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EDITORIAL NOTES.

MR. ALFRED BELL has presented to the Sedgwick Museum, Cambridge, a manuscript catalogue compiled by himself of the Newer Tertiary Flowering Plants of Great Britain; in each case localities and geological horizons are recorded. The catalogue will be available for reference by those desiring to consult it, but since only one copy exists this cannot be allowed to leave the Museum. Mr. Bell hopes to compile a similar catalogue of the flowerless plants.

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AT the risk of becoming tedious and to avoid misunderstanding, we find it necessary to refer once again to the subject of illustrations in the GEOLOGICAL MAGAZINE. We wish to emphasize the fact that under present economic conditions plates must be considered a luxury, and with much regret we are compelled to insist on a strict rule that all such must be paid for by the author, the approximate cost of a plate being about £4. With regard to text-figures the situation is that the cost of a line-block is about the same as that of an equivalent amount of type; therefore, we wish to urge on contributors the desirability of illustrating their papers by means of line drawings instead of photographs. For such we shall henceforth make no extra charge, and in our opinion as a rule drawings are much more effective than photographs for nearly all geological purposes: they enable the artist to emphasize the essential points and to omit extraneous details which only serve to distract attention from the real object of the illustration.

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ONE of the most notable signs of the times with regard to the recent progress of geology in this country is the extent to which discussions of theoretical questions of petrogenesis are now being transferred to meetings of technical societies and to the periodicals specially devoted to economic geology. We wish to refer specially to the animated debates that have recently enlivened the proceedings of the Institution of Mining and Metallurgy and to some excellent papers on petrological subjects in the pages of the *Mining Magazine*. Although some of the ideas put forward in these quarters are doubtless heretical, they do at any rate show originality and thought. It is by way of heresy that progress is made. It is greatly to be feared, however, that many geologists never see these publications, and for that reason attention is called to them here. A theory is not necessarily negligible because it is based on economic data, and the future of petrology is likely to be underground.

ORIGINAL ARTICLES.

On the Overlap of the Upper Gault in England and on the "Red Chalk" of the Eastern Counties.

By F. L. Kitchin, M.A., Ph.D., and J. Pringle, F.G.S.

(*Concluded from p. 166.*)

III. The "Red Chalk".

Norfolk.—The so-called Red Chalk is visible in two quarries at Snettisham, but the exposures there are less favourable for investigation than the well-known section to be seen in the cliff north of Hunstanton. The thin rock-bands there comprised under this title have given rise to much discussion amongst geologists, whose views have been summarized by Mr. W. Whitaker and by the late A. J. Jukes-Browne.[1] The Red Rock, not more than 4 feet thick at this locality, has been variously referred by different authors to the whole Gault formation, to the Upper Gault, to the Upper Greensand, and to the Lower Chalk. So long ago as 1869, the Rev. T. Wiltshire published an illuminating paper in which he described the characters of the three beds that can be recognized as composing the red band.[2] Chiefly on the basis of the fossils found in the two lower beds he made a correlation with the Upper Gault of Folkestone. The late Professor Judd and Professor C. Barrois emphasized the fact that the Red Rock is unconformable with the underlying Greensand, but conformable with the overlying Chalk. Professor Barrois was so impressed by this fact and by the unequivocal character of the fauna that he correlated the red beds with his zone of *Ammonites inflatus* (Upper Gault).

Our examination of the Red Rock at Snettisham and Hunstanton, amplified by a study of the collections of fossils at Cambridge and elsewhere and by specimens of zonal value collected by ourselves, convinces us that no horizon below the Upper Gault is represented. All the ammonites we have seen are Upper Gault forms. The records of "*Ammonites interruptus*" from these beds, based upon the erroneous identification of hoplitids of the Upper Gault with those of the *interruptus*-zone, have proved misleading. We have found *Inoceramus sulcatus* in the lowest bed, only some 10 inches above the base.

We are of opinion that the top bed, 1 foot thick, which has not yielded any Gault ammonites, should be regarded as forming the base of the Lower Chalk. It is a reddened lower part of the overlying "Sponge Bed", which is not similarly stained. Except for the

[1] W. Whitaker, "On Things in General and the Red Chalk of Norfolk in Particular": *Proc. Norwich Geol. Soc.*, vol. i, pt. vii, 1883, pp. 213–22. A. J. Jukes-Browne, *The Cretaceous Rocks of Britain*, vol. i (*Mem. Geol. Surv.*), 1900, pp. 294, 296.

[2] T. Wiltshire, "On the Red Chalk of Hunstanton": *Quart. Journ. Geol. Soc.*, vol. xxv, 1869, p. 185.

adventitious coloration of the uppermost red bed and the presence in it of minute polished black grains, there is close lithological resemblance between these two strata. Both have the same nodular aspect, and are characterized by the same peculiar ramifying concretionary structures (absent in the two beds below) and by the presence of numerous *Inocerami*. One of these shells seen by us in the uppermost red bed belongs, we consider, to *Inoceramus crippsi* Mantell, which also occurs in the "Sponge Bed". We saw also in both these beds *Inoceramus tenuis* Mantell and a small *Terebratula*, distinct from those occurring so commonly in the lower red beds, as well as a bryozoon (common) and *Spondylus latus* (J. Sow.), neither of which was found lower down. It must not be forgotten that S. Woodward[1] reported the rare occurrence of "*Ammonites varians*" in the Red Chalk, a record which unfortunately cannot now be tested, since the whereabouts of the specimen or specimens is unknown.

The occurrence of Chalk fossils in the topmost red bed probably gave rise to the view held by Gunn[2] and by Mr. W. Whitaker that the Red Chalk should be regarded as the basal part of the true Chalk series. The claim made by Gunn that the latest fossil types, not the earlier ones, must be used in identifying the age of a deposit, sound in itself, was nullified in this case by his regarding the whole of the red strata as of one age. Had he known that the fauna of the uppermost red bed has a different character from that of the two lower beds, he would probably have realized that the base of the Chalk series includes only the uppermost foot of the Red Rock.

We have been able to detect no sign of a break between the base of the Red Rock at Hunstanton and the overlying unstained Chalk; and we feel bound to regard this as an exceedingly condensed series laid down under conditions of slow accumulation, representing a facies of sedimentation for the most part different from that exemplified in the corresponding rocks farther south. Professor Barrois stated that the zone of *Pecten asper* is absent in Norfolk. The familiar development of this zone elsewhere, always as a glauconitic sandy deposit carrying a special faunal facies depending on sub-littoral conditions, precludes its recognition in an area where the facies is so strongly contrasted. Its attenuated equivalent may well be there. Similarly, the lowest bed of the *varians*-zone of Wiltshire and Dorset, with the fauna that includes *Catopygus columbarius* Lam., *Terebrirostra lyra* (J. Sow.), and other characteristic species, in all probability has very condensed representation in some part of the uppermost red bed at Hunstanton.

The well-known lenticles of fossiliferous limestone found at Harris's sand-pit at Shenley Hill, near Leighton Buzzard, have been correlated by us with the basal bed of the *varians*-zone. Some of the gritty

[1] S. Woodward, *An Outline of the Geology of Norfolk*, p. 54, Norwich, 1833.
[2] J. Gunn, "Notes on the Red Chalk of Hunstanton": *Proc. Norwich Geol. Soc.*, pt. i, Session 1877–8, p. 23, Norwich, 1878.

lenticles have the character of a limestone-breccia, a composite rock containing many fragments of pinkish limestone, often showing minute, polished black grains. The closely similar rock occurring at the base of the *varians*-zone at Matringhem, in Northern France, has yielded ammonites of the *varians*-fauna, as communicated to one of us in conversation by Dr. P. Pruvost. For many years we have been struck by the lithological resemblance between the pink limestone-constituents in the lenticles at Shenley Hill and the paler parts of the uppermost red bed at Hunstanton, which is striking. It must be noted that the specimens of *Terebratula capillata* d'Archiac found in the uppermost red bed are identical with those occurring in the pink limestone at Shenley Hill. This species is found in the *varians*-zone in this country and in France. The record of its occurrence in the lower red beds at Hunstanton requires to be tested, while there are ample reasons for believing that the similar *Terebratula* occurring in the Lower Greensand of Upware belongs to a separate stock. It suffices for our present purpose to point out that limestone closely akin to that found in the uppermost red bed at Hunstanton entered into the composition of the basal bed of the *varians*-Chalk of more southerly districts. A further discussion of the facts and their implications would involve a somewhat lengthy digression and must be omitted here.

Lincolnshire and Yorkshire.—We have as yet been unable to visit more than two sections in Lincolnshire, in which county the Red Rock passes transgressively across the Lower Greensand. In places a sandy basement-bed has been observed, and the red colour persists up through an increasing thickness of the Chalk above. *Inoceramus sulcatus* has been found at South Willingham. Hill recorded *Ammonites interruptus* at Withcall, but we have already pointed out that fossils so named from the Red Rock have been wrongly identified.

In Yorkshire the extension of the overlap of the "Red Chalk" on to older rocks is well known. At North Ferriby we have examined the relation of the transgressive beds to the substrata and find that they there rest upon a clay belonging either to a basal Kimmeridge or Upper Corallian zone.[1] At South Cave the "Red Chalk" probably lies on Corallian clay. At that locality *Inoceramus sulcatus* and *Ammonites rostratus* were recorded by Hill,[2] who also noted the occurrence of *Inoceramus sulcatus* at Wharram Grange. At Market Weighton, where the base of the Red Rock is markedly conglomeratic, it can be seen resting on the clays and ironstones of the Lower Lias. Mr. T. Sheppard kindly drew our attention to a newly made opening at the Rifle Butts in the Goodmanham Valley, and accompanied one of us on a visit to this locality. It was observed here that the basal transgressive bed contained constituents of variable character, including much oolitic material.

[1] "Summary of Progress for 1920": *Mem. Geol. Surv.*, 1921, p. 63.

[2] W. Hill, "On the Lower Beds of the Upper Cretaceous Series in Lincolnshire and Yorkshire": *Quart. Journ. Geol. Soc.*, vol. xliv, 1888, p. 347.

Along the northern border of the Wolds the formation is seen to change, and at Speeton there is a thin basal series of variegated marls only some 3 ft. 6 in. in thickness, overlain by about 30 feet of red and mottled nodular marly Chalk. These red strata were for long considered to be an expansion of the Hunstanton Red Rock. Jukes-Browne, who formerly adhered to this view, afterwards placed 28 feet of these beds in the Lower Chalk (*varians*-zone). On the occasion of our visit to this locality we were fortunate in seeing an exposure of the marls below this red Lower Chalk. We were able to confirm in the main the details given by Mr. Lamplugh in 1889.[1] We saw the glauconitic seam with eroded nodules resting directly on the black Aptian clay. Within the lowest foot we noticed the presence of *Inoceramus sulcatus* Park. and a few other lamellibranchs, all poorly preserved. The streak of dull reddish clay above this was readily recognized. In the uppermost 2 feet of marly shale were found numerous specimens of *Inoceramus anglicus* Woods and impressions of hoplitid ammonites. These marls belong to the Upper Gault, a fact proving that there is a non-sequence between them and the Aptian clays below, representing a considerable gap in time.

This is contrary to the view put forward by Mr. Lamplugh, who considered that the Speeton Clays most probably form an unbroken series from the Kimmeridge Clay up to the Chalk.[2] The base of the Spilsby Sandstone lies discordantly upon the Kimmeridge Clay in Lincolnshire, where the whole of the Portland Beds are absent.[3] A continuation of the same unconformity, between the Upper Kimmeridge Clay and the base of the Lower Cretaceous clays, is evidently marked by Bed E at Speeton, where the Portland zones are likewise unrepresented. The Lower Cretaceous clays of Speeton are thus limited below and above by non-sequences of some magnitude. It must be recognized that the transgressive Upper Gault, represented to the west of the Wolds and in Lincolnshire in the form of Red Rock, has here assumed a different aspect. In this connexion it may be remembered that at Holkham Hall, about 12 miles eastward from Hunstanton, a comparable change has been recorded. A well-section showed the presence of clay, described as Gault, beneath a "Red Marl".[4]

The thin bed of smooth, red marly Chalk overlying the Upper Gault marls at Speeton, and forming a passage to the Lower Chalk, seems

[1] G. W. Lamplugh, "On the Sub-divisions of the Speeton Clay": *Quart. Journ. Geol. Soc.*, vol. xlv, 1889, p. 603, fig. 8.

[2] Loc. cit. Also "On the Speeton Series in Yorkshire and Lincolnshire": *Quart. Journ. Geol. Soc.*, vol. lii, 1896, p. 197.

[3] W. A. E. Ussher, A. J. Jukes-Browne, and A. Strahan, "The Geology of the Country around Lincoln": *Mem. Geol. Surv.*, 1888, p. 82. J. Pringle, "Palæontological Notes on the Donington Borehole of 1917." "Summary of Progress for 1918": *Mem. Geol. Surv.*, 1919, p. 51.

[4] W. Whitaker, "The Well-Section at Holkham Hall, Norfolk": *Proc. Norwich Geol. Soc.*, pt. i, Session 1877–8, p. 16, Norwich, 1878.

to have yielded no distinctive fossils. Our examination of the reddened and mottled Chalk above satisfied us that the allocation of those beds to the Lower Chalk by Hill and Jukes-Browne was correct.

IV. Concluding Remarks.

In the foregoing notes we have endeavoured to bring into proper relationship some of the main facts concerning the overlap of the Upper Gault in England. The abundant evidence for this extension of the sea-floor in the marginal regions of the area of deposition can only be rightly understood if due attention be paid to the age-determination of the basal part of the Gault exposed in the different localities. When the available geological accounts of these rocks published during recent years are examined, it is surprising to find how often the true meaning of the facts has been overlooked. This has too frequently been due to the neglect of fossils or to an imperfect understanding of their significance. In fact, the broad methods of geological cartography, divorced from accurate palæontological work, have been too much in evidence. In many cases it can only be inferred from their writings that Jukes-Browne and other well-known geologists believed the Lower Gault to pass transgressively over older beds, whereas, by closer examination of the strata, we have found that it is in reality the Upper Gault. Professor Barrois had clearer conceptions on this point; and it is much to be regretted that subsequent work was not more carefully built upon the foundation of astute observation and deduction so well laid by him in 1876.

We have followed this overlap in a direction where, to the west, the facies of the deposits is traceable through the region of silty and sandy clays to a more purely sandy and shelly littoral development. Again, in the south central counties we have found at times, in the area of clay deposition, evidence of tranquil sedimentation where molluscan life soon found a bearable habitat on the newly invaded ground; or, again, abundant signs in the scarcity of fossils and the brecciated character of the lowest clays that rapid accumulation and turbid-water conditions had delayed these adjustments. And, finally, in the eastern counties, we have seen the approach to a region of much scantier, clearer-water calcareous deposition, where there is a great condensation of the strata. Our observations at Grimston and Roydon are particularly significant in this connexion.

In tracing these developments, certain faunal constituents of the lower part of the Upper Gault have been of great value, particularly those that characterize Bed IX at Folkestone. These indicators have led us to conclude that one general movement of depression was responsible for the transgressive extension of the Gault strata in this country. The *interrupius*-Gault is found always to rest upon the *mammillatus*-zone, and these beds have a much more restricted lateral distribution than the Upper Gault. These

lower strata are not seen westward of mid-Dorset; towards the north they do not extend beyond West Dereham. Indeed, these most westerly and northerly occurrences may only be isolated patches. Both at Okeford Fitzpaine and at West Dereham the Lower Gault has been denuded down almost to its base. At Okeford Fitzpaine these beds are far removed from their nearest outcrop; to the south of West Dereham they are absent in places and the surface of post-*interruptus* denudation is situated almost at the base of the Lower Greensand. Whilst there is evidence that a certain degree of tilting and general planation of the Lower Gault and older strata took place before Upper Gault deposition began, the facts just mentioned seem to suggest that some shallow folding of the beds may have taken place before the transgression and that, here and there, remnants of the Lower Gault in the synclinals have escaped total removal.

While these considerations arising out of the present study may throw light on the irregular occurrence of the *mammillatus*-zone in this country, which has frequently been the subject of comment, the extensive erosion accompanying this transgression at the close of Middle Albian time introduces a factor to be reckoned with in any comprehensive study of the Lower Greensand. The uncertainty in correlating the sandy strata which, in different localities, appear to form the top of the Aptian Series has always been great, owing to the sparsely fossiliferous nature of these deposits. The difficulty is increased by the knowledge that erosion of these beds had taken place here and there with great local inequality before the deposition of the Upper Gault. To mention one example, the true position of the Carstone of the Hunstanton district has never been ascertained; possibly the best clue is to be sought in a study and correlation of the fauna of the Snettisham Clay, a desirable subject for investigation. The so-called "Carstone" of Sandown Bay, Isle of Wight, is probably on a much higher horizon. A transgression of the *mammillatus*-zone must also have produced its local effects on the underlying sands. At Okeford Fitzpaine that zone rests almost directly upon Kimmeridge Clay, while we have recently obtained evidence of a corresponding unconformity of pre-*mammillatus* date in Bedfordshire and in Norfolk.

Of the movements that gave rise to transgressions during Cretaceous time in this country, that which produced the Upper Gault overlap has left the most conspicuous effects. It was one of the several widespread movements which brought about the remarkable extensions of Upper Albian and Lower Cenomanian deposits in many parts of the world.

Our examination of the "Red Chalk" of Norfolk has led us to correlate its lower three-quarters with the Upper Gault, its uppermost quarter with the Lower Chalk, perhaps including the *Pecten apser* zone. We regard these beds as a much condensed continuous series. At Speeton we have found the Upper Gault to be repre-

sented by the few feet of variegated marls which there rest non-sequentially upon Aptian clay and are overlain by red and mottled Lower Chalk.

In view of recent detailed work on the Albian zones, we should perhaps remark that in the foregoing pages we have used the terms "*interruptus*-zone" and "*rostratus*-zone" in the general sense of existing stratigraphical classifications. As regards the lowest beds of the Gault at Black Ven (previously assigned by some authors to the *interruptus*-zone), Dr. W. D. Lang has informed us, since the first part of this paper appeared, that he has obtained ammonites from those beds (his beds 1, 2, and 3) and that Dr. L. F. Spath has pronounced them to be Upper Gault forms.

The Geology of Portuguese Nyasaland.

By Robert R. Walls, M.A., B.Sc.

(WITH PLATES VII AND VIII.)

PORTUGUESE NYASALAND is the name given to the most northern part of Portuguese East Africa, lying between Lake Nyasa and the Indian Ocean. It is separated from the Tanganyika territory in the north by the River Rovuma and from the Portuguese province of Mozambique in the south by the River Lurio. The territory measures about 400 miles from east to west and 200 miles from north to south and has an area of nearly 90,000 square miles. This territory is now perhaps the least known part of the once Dark Continent, but while the writer was actually engaged in the exploration of this country in 1920–1, the Naval Intelligence Division of the British Admiralty published two handbooks, the *Manual of Portuguese East Africa* and the *Handbook of Portuguese Nyasaland*, which with their extensive bibliographies contained practically everything that was known of that country up to that date (1920). These handbooks make it unnecessary in this paper to give detailed accounts of the work of previous explorers.

The geological information is meagre, and is obtained chiefly from the reports of Livingstone (1862–6), Thomson (1881), and Huddart (1906). Practically all the more important expeditions into this territory have been made via the River Rovuma and its tributary, the Lujenda in the north, or from Lake Nyasa in the west, and the south-eastern parts have been entirely neglected. It was in the south-eastern part that the writer did most of his explorations, so that the whole territory has now been at least roughly surveyed. Generally speaking, the country rises from the level plains along the coast to high mountainous land near Lake Nyasa. Several large rivers are shown on the map rising in the mountainous interior and draining into the Indian ocean, but only two of these rivers, the Rovuma, with its tributary the Lujenda, in the north, and the Lario in the south, contain running water all the year round. The outstanding feature of the country is its dryness, large stretches being practically

FIG. 1.—Mangrove Swamp being covered again by sand within the uplifted area of Pemba Bay.

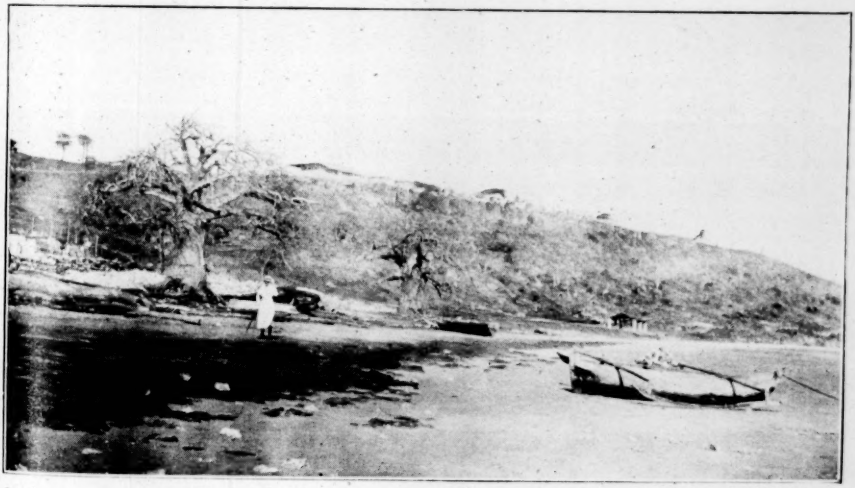


FIG. 2.—Raised beach at Pemba Bay. The cliff is the fault-line marked B on the Sketch-map, and is composed chiefly of mud with a thin sandstone cap.

[*To face p. 200.*

PORTUGUESE NYASALAND

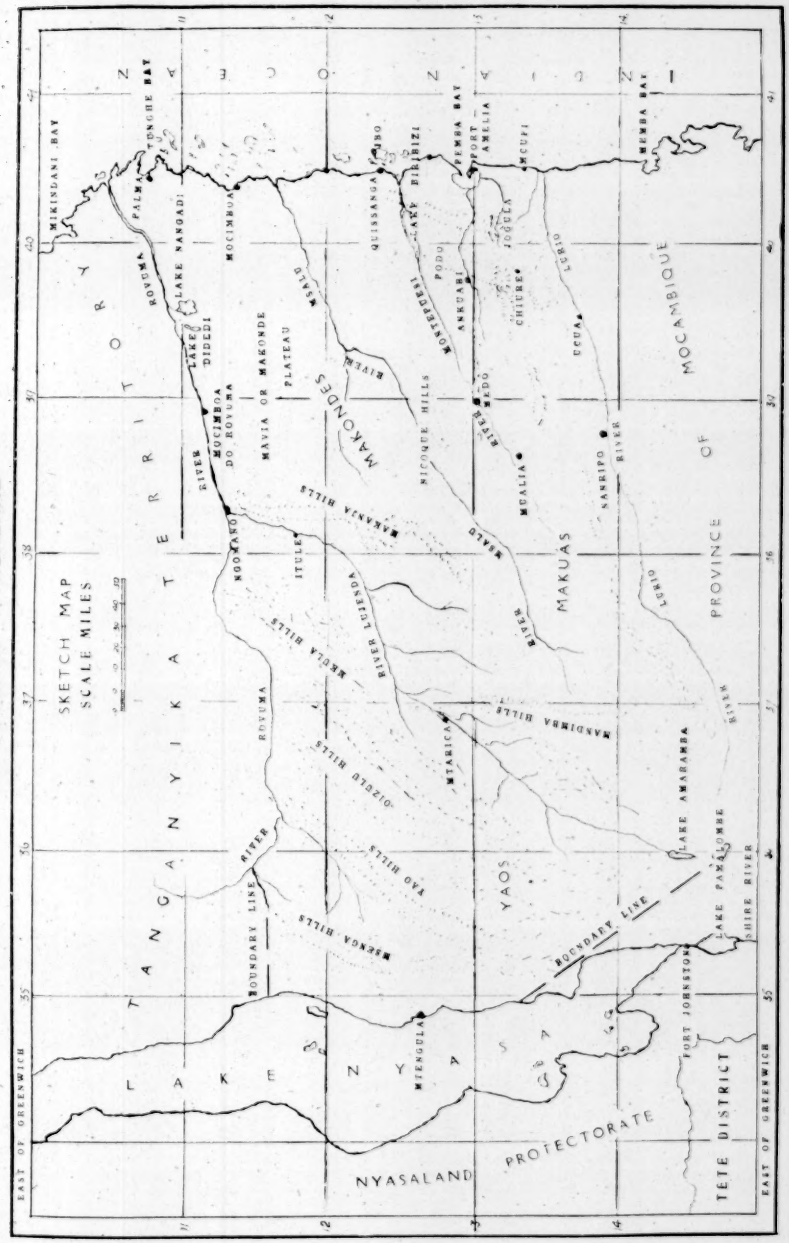


FIG. 1.—Sketch-map of Portuguese Nyasaland.

uninhabited for the greater part of the year on account of the drought. The whole of the interior is covered by a dense dry bush with elephant-grass and bamboo growing to an average height of 12 or 15 feet, and many larger trees yielding good and valuable timber. It is seldom possible to see 200 yards ahead. Geological surveying in such a country is naturally very difficult. Rock outcrops are comparatively few, often hidden away in the bush, and owing to the lack of accurate maps only the most general survey work can be attempted.

The coast-line of Portuguese Nyasaland is low, sandy, and shelving, and good harbours are few, with the outstanding exception of Pemba Bay, which will be discussed more fully later on. Behind and among these great sandy stretches, sedimentary rocks of Tertiary or perhaps Cretaceous age appear. These sedimentaries are invariably calcareous sandstones or shelly and coralliferous limestones. Everywhere they have the appearance of consolidated shallow sea deposits, and in many places they are thrown up to form raised beaches between 200 and 300 feet high. An oolitic structure is very common among these calcareous sandstones, evidently due to percolating water which dissolves the lime and recrystallizes it round the sand-grains. These latter, although not of great extent, are of considerable economic importance, furnishing the only suitable building stone in the country. Coral abounds on the coast, and is burned by the natives for lime. Coral rock forms a number of islands lying off the Montepuesi River, of which the largest is Ibo, containing the town of that name, one of the earliest settlements of the Portuguese in East Africa and still practically the only town worthy of the name in the whole territory.

Conspicuous features on the coast are the mangrove swamps, which are particularly extensive at or near the mouths of the numerous rivers, even though, as a general rule, these rivers do not contain running water for more than two months in the year. Thus all the islands off the mouth of the Montepuesi River are joined together and to the mainland by mangrove swamps, and the western shore of Pemba Bay is bordered by mangrove swamps, which are rapidly encroaching on the bay. The study of these mangrove swamps is exceedingly instructive to the geologist. On the seaward edge of such swamps the trees grow directly from shelly sand in clear water. But the traveller does not penetrate far into the swamp until a fine, green, slimy mud is encountered, which makes progress slow and even dangerous. If this is uncovered at low water it is oily and evil-smelling, and a heavy, oppressive air fills the whole swamp. Stagnant pools of rotting vegetation occur here and there, and over these the will-o'-the-wisp lights play at night. Sometimes the mud is so black with carbonaceous matter that it seems as if the traveller were walking through a quagmire of coal-dust. Crabs of all colours and sizes abound everywhere, crawling over the mud and running up and down the trees. There are millions of crabs, and

the traveller can scarcely put his foot down without crushing several at every step. The result of such a huge population of crustacea must naturally be to add a big percentage of lime to the mud, and when a sample of this mud is dried and then treated with dilute acid it usually gives considerable effervescence. The mud of the mangrove swamps is very fine and plastic to the touch, and quite characteristic.

But there have been considerable changes of level along this coast, and very often this mud is covered again by the sandy deposits of the shore and the mangrove swamp may disappear locally. A mangrove swamp disappearing in this fashion is shown in Pl. VII, Fig. 1. In fact, it is pretty safe to state that in earlier Tertiary times the mangrove swamps were much more extensive than they are to-day. Where the whole region has been raised subsequently as in the section shown in Pl. VII, Fig. 2, calcareous sandstones of raised beaches are found lying on impervious clay, which is identical with the mud of present day mangrove swamps. This is of immense economic importance to a country which suffers so much from drought. The impervious clay holds up the water in the porous sandstone, and it is to this that the small villages on the coast area owe their very existence. Water is thus found in the neighbourhood of Pemba Bay at from 30 to 40 feet below the surface all the year round, and at Ibo at about the same depth. More extensive boring for water in the raised beaches along the coast is absolutely necessary if the country is ever to support even a black population.

The Tertiary deposits of the coast area measure less than 20 miles across in the south, though they are rather more extensive farther north. Immediately to the west of this coastal strip an area of extreme metamorphism is found which extends right across to Lake Nyasa. The rocks of this area appear to belong to the very oldest Palæozoic formations with very small areas which might be of Carboniferous age. These will be discussed again. The Tertiary rocks of the coast area lie unconformably on these metamorphic rocks, and though a complete section can nowhere be seen so far as the writer knows, yet the Tertiary deposits would appear to be of no great depth, possibly about 400 or 500 feet at most.

About 40 miles west of Pemba Bay there is a marked north-south ridge, running more or less parallel with the coast. The ridge is really a steeply folded anticline of hard metamorphic rock—generally speaking, gneiss. The ridge is made more conspicuous by a series of "humps" at intervals along its length. About half-way between this ridge and the coast is a second, but less conspicuous ridge, roughly parallel to the first and very similar in its construction. In the region west of Pemba Bay, however, this minor ridge is pierced and broken by a later intrusion of granite, and the folded anticlinal structure of the whole is not so clearly marked. These two anticlinal ridges run north across the Montepuesi River, but are not so conspicuous in the north, where the calcareous sandstones of the

coast extend much further inland, forming what has been called the Mavia or Makonde Plateau. The exact area of the Tertiary rocks on this Makonde Plateau has never been mapped out, but the deposits are known to be of no great depth and to rest unconformably on metamorphic rocks of much greater age. The two north-south ridges first mentioned are conspicuous features to anyone crossing the country in the south from the Indian Ocean, and the folding—except where it has been complicated by intrusive granite—into two anticlines with a syncline between is very distinct.

To the west of these two north-south ridges gneiss and associated foliated rocks cover almost the whole country. Careful plotting of these metamorphic rocks is almost impossible for lack of accurate maps on a sufficiently large scale, but some general observations may be made. The most important feature to be noticed is that the country rock now shows folding in a direction at right angles to that already mentioned. Over the centre and south of the country the ridges and lines of foliation run in an east-west direction, and the compression thrust which produced these ridges has been just as intense as that which produced the north-south ridges over the rest of the country. The folding of the rocks in this country will be treated more fully later on. The gneiss is predominant everywhere, but varies greatly in its texture. Sometimes it is extremely coarse with conspicuous felspar crystals. More usually it is crushed considerably until in hand specimens it scarcely appears like gneiss at all, and it is only in a large scale on the field that the real nature of the rock can be ascertained, but all gradations between the two types can be seen in traversing a few miles of country. Often felspars are conspicuous by their absence, and the rocks appear as banded quartzites with considerable quantities of mica. Yet, taking the whole outcrop together, it would not be wrong to state that the rock was gneiss. Iron ores occur very frequently in bands in the gneisses, and is the only mineral of economic importance found in the country.

Bands of schist are not uncommon interfoliated with the gneisses, but they are, generally speaking, remarkable for their thinness and variety of form. Garnet schist and mica schist are most often met, but there are also considerable seams of graphite schist. Attempts have been made in the past to work this graphite, especially at Mualia, but owing to the fact that it is so interlaminated with gneiss and grit it has proved of no commercial value. Associated with these graphite schists are peculiar black bands often found in the gneiss. These bands are likewise very thin—1 or 2 inches at most—and usually dull, though sometimes showing an adamantine lustre. The dull variety is really black flint, but the lustre shown on other varieties sometimes suggests anthracite, and a bigger proportion of carbon. It cannot be made to burn by itself, however, and if burned in the blowpipe flame it leaves a huge quantity of ash. There is evidently some carbon about it, but quartz predominates.

The material, strange to say, is never found of a slaty structure, although occurring in highly foliated rock. These black bands in the gneiss were often found in the neighbourhood of graphite schist, and suggested some connexion in origin which could not now be recognized in the metamorphic state.

Bitumen and coal are occasionally found in the valleys of the Rovuma and Lujenda, and were first commented on by Livingstone. Both are of a very shaly nature, and the carbon percentage is small. The discovery, however, gave rise to fantastic tales of rich coal-fields, and several expeditions were sent out at various times to search for coalfields, with no success whatever. The most important expedition was Thomson's in 1881, when he went out to investigate for the Sultan of Zanzibar, who then exercised jurisdiction over this area. The most noted outcrop of this so-called coal is at Itule, on the Lujenda River, but only a few seams of a few inches thickness are known altogether. Owing to the folding the beds are lenticular and not extensive and therefore of no commercial importance. Their occurrence, however, is interesting from the geological point of view, and may indicate that the rocks in that neighbourhood are of true Carboniferous age. Thomson assumed that these rocks were of Carboniferous age, and let down into the gneisses by trough faulting, but he made no attempt to map the foliation of the rocks carefully in the districts over which he travelled. It is worthy of note that these carbonaceous bands occur themselves in highly metamorphic rock, and seem to have themselves suffered in the metamorphism, e.g. the transformation of coal into bitumen. The thin black bands of anthracite-looking material in the gneisses were also noted by Thomson. In the present state of our knowledge it would not be wise to correlate the thin black bands in the gneisses throughout the country generally with the one or two seams of shaly coal or bitumen found at Itule on the Lujenda.

The valley of the Lurio in the extreme south of Portuguese Nyasaland is remarkable as being made up of banded quartzites, with little or no gneiss and inconspicuous mica. These quartzites are particularly hard and strongly marked off in colours of black, red, yellow, white, brown, purple, etc. In fact, they should be more properly termed banded jaspers. For 150 miles up the river, and possibly much more, these quartzites all dip to the north, generally at angles of about 50 degrees. The Lurio valley is many miles wide, and it is practically all composed of quartzites; yet the exact width of these quartzites is difficult to determine as they seem to grade into the gneisses in some places. More often, however, intrusive granite is found along what appears to be the line of junction. Across the valley in the territory of Mozambique in the south the gneisses could be seen again as huge corrugated mountains along the sky-line. Very occasionally the quartzites show sedimentary origin and beds of rounded flints appear. These are not common however. The quartzites of the Lurio have many

similarities in the field with the rocks of the Swaziland system in the Transvaal, and as they are absolutely devoid of fossils and appear to lie on a crystalline complex of granite and gneisses it is probable that they belong to the very oldest Palæozoic rocks. As in the Swaziland system, bedded iron ores are very common. At one point, nearly 150 miles from the mouth of the Lurio, the quartzites form steep escarpments, and the iron ores are well exposed. As the rock weathers the heavier iron ores accumulate below, while the lighter materials are washed away in the rainy season. The natives gather the ore by hand and smelt it with wood charcoal. They show remarkable ingenuity in fashioning spear-heads and axes in this crude manner, though the iron is naturally very soft and not of much value.

Throughout the gneisses of the interior and the quartzites of the Lurio valley intrusive granite is very prolific. The granite always appears of much later date than the intruded rock, and yet often ramifies through the gneisses and quartzites in such a fashion as to suggest that the granite itself has been subjected to subsequent folding with the country rock. A good instance is seen in the granite intrusion immediately to the west of the Tertiary deposits in the immediate neighbourhood of Pemba Bay. Seams of white quartz are prolific over all the metamorphic rocks of the interior, and are rather a conspicuous feature. Seams less than 2 inches thick can often be traced for many hundreds of yards, piercing gneiss, schist, and quartzites alike in wavy lines, quite independent of the bedding or folding.

The rock outcrops of this country deserve particular note. The Tertiary deposits of the coast have been thrown up to form raised beaches generally marked off sharply by fault-lines. These Tertiary deposits retain their horizontal bedding to a marked extent, and are free from folding and contortion although faulted. The outcrops of the older rock of the interior are very distinct however. They are typical Inselberge or isolated mountains, though of different architecture. They may rise to a height of 500 feet or more above the general level or they may appear a few inches only above the soil in the bush. (See Pl. VIII.) They may be differentiated into : (*a*) Bosses of granite evidently intrusive and irregular in plan ; (*b*) steep anticlines of folded metamorphic rock and gneiss oval in plan ; (*c*) escarpments of metamorphic rocks and quartzites generally more elongated than the latter type. These three types have remarkably smooth surfaces, so smooth, in fact, that it is very unusual to find any soil or plants other than the most minute species growing upon them. The other type (*d*) of Inselberg is sharply distinct from the three foregoing types, and is composed of huge broken and contorted boulders lying promiscuously one on the top of the other. This latter mountain is typical of regions where intense contortion and crushing of the rocks have taken place by folding in two or more different directions. For example, it is found in

FIG. 1.—Typical Inselberg at Ankuabi seen from the west. The axis of the fold is north–south.

FIG. 2.—Typical Inselberg or Whaleback Formation in the bush of Central Portuguese Nyasaland. It is composed of gneiss with east-west foliation.

[*To face p. 206*

the south-east of the country at Jogula and Pomune, where the east-west folds of the Lurio valley meet the north-south folds of the two anticlinal ridges which run parallel with the coast. It is found, also, in the Medo region of the interior, where the east-west folds of gneiss again meet folds at right angles more or less. These latter Inselberge represent areas of extreme compression, and the rocks have been broken and thrown up. All the boulders are severely contorted, and show signs of the intense strain to which they have been subjected. This type of mountain is naturally not smooth in outline like the former three types, but broken and rent in all directions. Huge cavities are found in them, generally the retreat of wild animals. There are extensive footholds for soils, and spiny prickly plants grow all over them with such natural entanglement that it is well-nigh impossible to force a passage to the summit.

But many of the folded whaleback formations of the interior have also snapped and broken by extreme compression, and when this has happened the smooth contour is naturally destroyed. These faults from their appearance are all of very recent date, and are marked by sharp edges. Plants grow and spread rapidly in the debris along these cracks and the action of weathering then tends to split them into folia which run parallel with the long axis of the formation. Although rapidly splitting up, however, they still show their original whaleback character.

The weathering of the rocks in this country also deserves notice. Owing to the shortness of the wet season, water plays a very small part in the denudation of the country. The chief weathering agent is insolation, the expansion and contraction of the rock due to alternate heat and cold, and in tropical countries this is no inconsiderable factor. Numerous travellers have commented on the sharp crackling sounds given off by the rocks in disintegrating by this agency. Insolation causes the rocks to weather in a scaly fashion, breaking off layer by layer as it were, and leaving the smooth rounded surface already commented on in the description of the first three types of Inselberge. On many of these Inselberge the contour was so smooth that it was impossible to break off a specimen with a geological hammer, and the exact nature of the gneiss could scarcely be ascertained by a cursory examination of the weathered surface. The products of disintegration give rise to a coarse, sandy soil, which accumulates in the valleys at such a rate that the rivers in their short season cannot remove it. All the river valleys are choked with sand and after a season of perhaps two months the rivers sink down and disappear in the sand in their own courses. So the corrugated mountainous nature of the country is being obliterated by the products of its own disintegration. Coarse sand is filling up the synclines and valleys and smoothing out the contours, and only the tops of isolated mountains now appear above the general level. These Inselberge may now be submerged in the sandy soil all but a few inches, in which case they are noticeable only by the

lack of vegetation and the natural "clearing" in the bush. (See Pl. VIII, Fig. 2.) But the vast majority of these outcrops all have the same appearance and smooth, rounded contours, like petrified whales in a sea of sand. This "whaleback" formation refers to the first three types of Inselberge mentioned above; the last type is only found in isolated districts, and is by no means common over the country as a whole. The sandy soil is the nursery of the dry bush vegetation, a vegetation which grows with remarkable activity during the short wet season, and covers the whole country.

With regard to the age of the rocks of Portuguese Nyasaland, it is practically certain that the bulk of the gneiss is Archæan. Yet folded and faulted into this gneiss are possibly rocks of later Palæozoic age. The quartzites of the Lurio valley and their similarity with the quartzites of the Swaziland system of the Transvaal have already been commented upon. It is probable that they lie upon the gneisses, although their line of contact is now more or less obliterated. Again, there are the carbonaceous beds found at Itule on the Lujenda. As coal they have no commercial value, but they are interesting as suggesting that there may be rocks of Carboniferous age in the metamorphic complex. Unfortunately none of the numerous prospectors have considered it worth while to map out the rocks of this region and so nothing has been added to our knowledge of this area since the time of Thomson. The lines of foliation of the rocks over the north and west of this territory have still to be plotted, and until this is done any statements regarding trough faulting and the possible age of these metamorphic rocks can only be in the nature of vague hazards. The coastal strip of more recent rocks still requires some careful geological scrutiny. Many writers have vaguely mentioned Cretaceous deposits, yet proofs that any of these rocks are of undoubted Cretaceous age have never been produced. The bulk of the deposits are Tertiary and many of them appear of very recent date. Fossils are fairly common in these deposits of the coastal area, though somewhat obliterated in many places by the action of percolating water. Much interesting work might be done in this area by a palæontologist.

The minerals of commercial value in this country require very little comment. The beds of impure shale coal and bitumen have already been discussed at length. The graphite in the schist might be worked in a small way in some localities and the mineral afterwards washed in settling tanks to separate out the grit. Iron ores, hæmatite, magnetite, and ilmenite occur in great quantity foliated in the gneisses and quartzites over the whole country, but the absence of coal and the natural difficulties of extraction render these deposits valueless at present. As with many other countries, before they have been thoroughly explored, wild and fantastic tales of great mineral wealth have spread, gold, silver, precious stones, copper, nickel, zinc, and tin being reported in great abundance. Subsequent investigations have never justified these reports,

however, and it is very doubtful whether any of these minerals occur at all in commercial quantities.

The chief geological feature in Portuguese Nyasaland is the intense compression and folding to which the whole country has been subjected, resulting for the most part in the formation of ridges and valleys running in a north-south direction. Lake Nyasa itself is supposed to occupy a huge fault-line in this direction. But there have been thrusts from the opposite direction as well, resulting in folds at right angles to the above, as, for example, in the valley of the Lurio and across the centre of the country. These two thrusts are quite distinct from each other, and have each affected many thousands of square miles of country. No traveller has yet mentioned, so far as the writer is aware, the occurrence of these two great earth thrusts in this country, yet these factors will be of vital importance when the geology of this territory comes to be studied in detail. The lines of foliation over the whole country must be plotted and the respective areas affected by these two great earth-thrusts mapped out. Much can then be learned with regard to the physical features of the country and the geological sequence of the rocks. Where the writer marked the boundary lines between the two areas in the south-east portion of the territory, much local contortion was evident and mountainous heaps of broken boulders had been thrown up as already described. To this phenomenon are also due the humps or whaleback formations along the line of the main ridges already discussed. It is not suggested that these two thrusts were contemporaneous. On the contrary, the bulk of the evidence seems to indicate that the thrust which produced the north-south ridges was subsequent to that which produced the east-west ridges of the central and southern areas. Indeed, there are many evidences that the former thrust is of recent geological date, and may, in fact, be still going on at the present day. These evidences are: (1) The raised beaches of the coast which, though they may now be 300 feet above sea-level, are all of recent age; (2) The fault-lines of the raised beaches, e.g. round Pemba Bay, which are still sharp and distinct, although the escarpment is composed of soft unconsolidated mud which is washed out by thousands of tons each rainy season; (3) the anomaly of the deep water of Pemba Bay in a shelving and silting-up coast; (4) the numerous rivers which come down from the interior and cut through the two north-south ridges parallel to the coast, and which are therefore older than these ridges; (5) the cracks occasionally seen where the folded rocks have snapped and which are invariably new and angular in appearance; (6) the folding of the more recent granites along with the older rocks into which they are intrusive.

It is only after all the evidences of a great earth-thrust from the east have been studied carefully that the geological formation of Pemba Bay becomes comprehensible, and the anomaly of this deep harbour on a low and shelving coast explained. Pemba Bay has an

area of just over 20 square miles, of which, perhaps, one-third is sufficiently deep for ocean-going vessels to anchor in. (See Sketch-map.) The eastern arm of the bay is a raised beach, nearly 300 feet high, thrown up on the hump of an anticlinal fold parallel to the two north-south folds farther inland. The "core" of the hump is nowhere exposed, so it is impossible to say whether it is folded gneiss or a granite intrusion. The bulk of the two first-mentioned north-south ridges is folded gneiss, but in the nearer ridge due west of Pemba Bay there is much intrusive granite. The "core", however, whatever its substance may be, appears to be of the humped whale-back formation which is so common over the entire country. The superimposed Tertiary rocks have not folded into the metamorphic complex, but have cracked into fault-lines, which are shown in the sketch-map. The main fault-line is north-south, but there are several minor faults veering round to the west, and so giving rise to the tongue of land which projects into the bay. The deep part of the bay apparently occupies, therefore, an original syncline in the metamorphic complex. It is deepest close to the fault-line on the eastern margin and shallows gradually to the west, where mangrove swamps are rapidly encroaching. Rivers flowing into the south and west bring down vast quantities of sand in their short seasons, which also help to silt up the bay on these sides. The raised portion is composed for the most part of soft unconsolidated mud, identical with the mud of mangrove swamps. This is protected by a thin cap of calcareous sandstone, which has been recrystallized by percolating water and is very hard. The mud, however, is rapidly falling away, and the sandstone cap breaks up into boulders forming screes down the steep face of the cliff. One of the minor fault-lines (marked B on sketch) is shown in Plate VII, Fig. 2. The figure in the foreground is standing on the same geological horizon—the calcareous sandstone cap—which appears again on the summit of the cliff in the background. The cliff face is the fault-line, composed almost entirely of soft mud, the sandstone cap being only between 30 and 40 feet thick. A well has been bored through the sandstone cap on the top of the hill to the underlying mud for water, and two wells have also been bored on the foreshore, not shown in the photograph, and water is again found held by the underlying mud. Water escapes along the junction line of the sandstone cap and mud on the cliff face shown in the photograph, and attempts have been made to secure this for a water supply. The storage tanks and pipe line, however, being set in the loose mud of the cliff face, fell away as the cliff crumbled. Except for the thin sandstone cap and occasional coral rock the boundary walls of Pemba Bay are composed of very loose unconsolidated material, which show a decided lack of structural stability and clearly indicate formation in very recent geological times.

Another most important natural feature must be considered, viz. the drying-up of the whole country within recent times. The rivers

which formerly carved out huge valleys for themselves across the country do not exist now except for perhaps two months in the year. The Rovuma and the Lurio, though they do persist throughout the year, shrink up to narrow and absolutely insignificant streams.

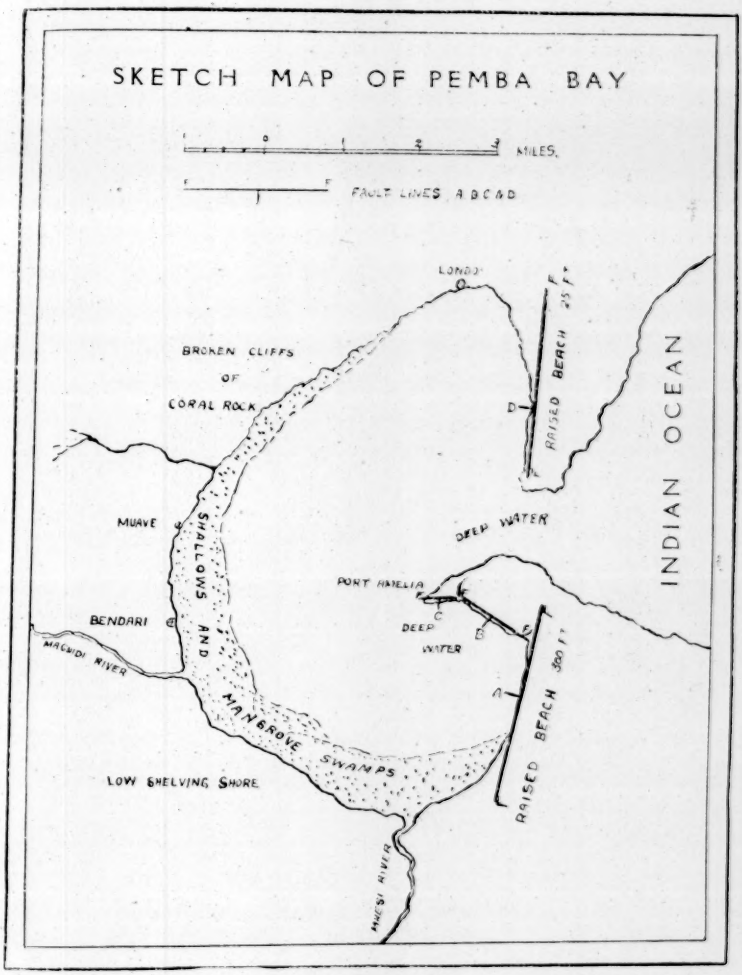


FIG. 2.—Sketch-map of Pemba Bay.

The mangrove swamps are isolated and in process of being buried up in sand. They are poor remnants of the great swamps which formerly stretched up and down the coast and left their traces in the soft greenish-grey mud which now underlies the sand of the

raised beaches in so many places. In the extreme west of the country the water-level of Lake Nyasa has been observed to fall considerably during the short time it has been known to Europeans. The want of water is terrible now, and is reflected in the annual famines and rapidly dwindling native population. The absence of water has been the most serious drawback to the development of this country, and demands immediate and careful study. Water can always be obtained by digging in the sand in the synclines and valleys and a few native wells exist in these situations, but no serious attempt has been made by Europeans to exploit these sources for water. It is not a difficult matter for a field geologist to map out likely sources of water, or to suggest suitable situations for boring; for example, the syncline between the two north-south ridges and the narrow strips immediately to the east and west of these ridges are good regions for a constant water supply, and are, in fact, the most fertile parts of the country. The River Montepuesi, where it crosses the syncline between these two ridges, broadens out into the great Lake Biribizi, which remains a swamp for months after the river has disappeared. This suggests that engineering attempts might be made to deflect the rivers in their short season into natural synclines to form lakes and so conserve the water supply. Water is also retained in the porous Tertiary rocks along the shores of the Indian ocean, whence it is already obtained by boring wells, as described above.

From the economic point of view, Portuguese Nyasaland is a decidedly poor country. Its mineral wealth, in spite of numerous reports to the contrary, appears to be nil. Its chief asset is the rich loose soil which results from the disintegration of the gneiss and granite, and which is exceedingly fertile when water can be obtained. The country will probably develop into a rich agricultural state once water supply has been assured. The rainfall is considerable, although the wet season is short, but exact figures are lacking. A large proportion of this rainfall is already conserved in the deep loose deposits which fill up the synclines and river valleys. Once the sub-arenaceous contours of the hard metamorphic rocks are plotted and new wells made in the larger synclines and valleys, the conditions in this impoverished country will be greatly ameliorated.

Morphological Studies on the Echinoidea Holectypoida and their Allies.

By Herbert L. Hawkins, D.Sc., F.G.S., Professor of Geology, University College, Reading.

XII. PSEUDOPYGASTER, A NEW TYPE OF THE ECHINOIDEA EXOCYCLICA FROM THE MIDDLE LIAS OF PERSIA.

PLATE IX.

(i) Introduction.

Liassic Irregular Echinoids are rare. The interest attaching to them is exceptionally great, and is enhanced by this rarity. Separation of Exocyclic from Endocyclic types can hardly have preceded the Rhaetic period; hence each Irregular form found in the Lias might be expected to display evidence as to the origin of its sub-class. It cannot be claimed that the few such genera known fulfil expectation. *Plesiechinus* (represented by *P. reynesi*) occurs in the "Charmouthian"; it is but little removed from "Regularity", but the Bajocian species *P. ornatus* (which is locally abundant) seems "just as good" in that respect. *Holectypus* appears in the Toarcian with *H. conquensis*; its occurrence at this horizon gives a striking illustration of morphogenetic acceleration, and thereby a negation to hopes of "genealogical" evidence. Species of *Galeropygus* are recorded from the Upper Lias; orthodoxy would probably repeat the preceding sentence here, but *vide infra*. The case of *Collyrites*, recorded from deposits of Liassic age, must surely be compared with that of *Holectypus*; for every feature of the Collyritidae is in violent contrast with "Regular" structures.

Loriolella should have accompanied these four genera in the foregoing paragraph, according to its founder, Fucini; but for reasons set forth below it deserves separate consideration. Not the least of these reasons is the discovery (by Lambert) that the periproct was enclosed by the apical system, so that *Loriolella* is not an Irregular Echinoid. Lambert places it near *Mesodiadema* and *Orthopsis*. Fucini's figures of *L. ludovici* are somewhat obscure; while comparison of his diagnosis of the genus with that given by Lambert & Thiéry (1911, "Essai de Nomenclature," fasc. iii, p. 195) arouses a passing suspicion that wholly different types are considered by the two writers. However, after careful study of Fucini's account, I feel convinced that his specimen was described *upside-down*. Only on such an assumption is it possible to reconcile the two generic diagnoses: without it *Loriolella* would be more extraordinary than its author realized. Then the "slightly concave upper surface" becomes the adoral surface; the ambulacra, "widest at the apex and gradually tapering towards the peristome," are inverted to conform with those of all other Echinoids; the interradial tubercles, "fairly large on the upper surface, becoming

indistinct on the lower surface," agree with Lambert's phrase " ces tubercules s'atrophient à la face supérieure " ; the " compact apical system with five apparently equal genital plates " is transformed into the " péristome extrêmement étroit, à scissures interambulacraires en fentes assez profondes " (Lambert) ; and the " central, exceedingly large peristome " is the " apex très large, occupant une grande partie de la face supérieure ". The only discrepancy in the two diagnoses unsolved by this inversion is in the description of the ambulacral pores, which, to Fucini, appeared diverse (" pori della serie interna sono spiccati e rotundi, quelli della serie esterna molto allungati obliquamente "), and to Lambert, " pores simples ". Possibly imperfect preservation misled Fucini ; anyhow, Lambert's account seems to me the more credible.

The foregoing lengthy comment on an obscure and confusing genus is necessary in view of the two specimens on which this paper is based. Some months ago my friend Professor D. M. S. Watson told me that he had seen, in the British Museum, two " Pygasters " in a collection of Persian Liassic Ammonites entrusted for study to Dr. F. L. Spath. At the earliest opportunity I sought out Dr. Spath, and the collection was promptly and courteously displayed. After the sensation of disappointment at the state of preservation (if such it can be called) of the specimens had somewhat abated, desperate examination of the less imperfect example was undertaken. Soon it appeared that most features of importance were more or less accessible, and that the labels attached to each specimen (" Pygaster, Kelat ") were not so grotesquely inaccurate as had seemed probable. It was obvious that the name *Pygaster*, even in its widest sense, could not be applied to the form ; but the periproct was typically Pygasterid, in form and position.

At the time of this preliminary view of the material, I had not seen Lambert's revised account of *Loriolella*, and several years had elapsed since I had read Fucini's paper. However, *Loriolella* was the only type that commended itself to my memory as comparable with the specimens before me. Mention of its name gave a pleasant surprise to Dr. Spath and myself. He explained that the Ammonite fauna from Kelat showed striking affinity with that from the Italian Lias, and that Fucini's monographs were in constant use for purposes of comparison. So that both of us were confirmed in our views by this unexpected coincidence.

Almost persuaded that the Persian Echinoids would prove congeneric with *L. ludovici*, I renewed acquaintance with Fucini's paper (1904, *Ann. Univ. Tosc.*, xxiv). Point by point the new specimens were compared with the description of the Italian type, and in many respects the agreement was extraordinarily close. But the " peristoma grandissimo " of Fucini's diagnosis seemed to counterbalance all the approximations, for the small size of that aperture is one of the most striking features of the Persian form. At that stage of study, the Kelat Echinoids seemed to represent a new genus closely akin to the " Exocyclic " *Loriolella*.

The next stage was spent in comparison of the new type with *Mesodiadema*. At first the nature of the surface-ornament afforded the best basis for this comparison; but gradually all of the visible features (except the periproct) came into line, until the Persian form proved nearer to *Mesodiadema* than to *Loriolella*, with the reservation just made.

The last stage in growth of my opinion on the problem opened in bewilderment. Lambert & Thiéry's "Essai de Nomenclature", fasc. iii, 1911, came into my possession. *Mesodiadema* and *Loriolella* occur there on the same page in direct sequence, thus confirming my use of both genera for comparison; but *Loriolella* seemed transformed! In a previous paragraph I have shown the apparent reason for this transformation; but there remained the greatest stumbling block of all. *Loriolella* had become a Regular Echinoid! The revised diagnosis, apart from its context, had almost succeeded in restoring my first opinion—the Kelat forms represented a new species of *Loriolella*! But the last sentence in Lambert's account —"L'un de nous a constaté que le périprocte ne s'ouvrait pas hors de l'apex"—sent me back to the better of the specimens to find if I had been deceived. The region of the periproct was developed further, even to the point of etching with acid, and examined wet and dry, with naked eye, lens, and microscope, directly and in photographs, and (most important of all) with half-conscious *expectation* of finding a narrow genital, or its scar, enclosing the aperture. But I am absolutely convinced that no such plate exists, and that no such plate existed (unless in earlier ontogenetic stages) in the new type. The periproct extends backward farther than in any species of *Pygaster*; the apical system, though practically invisible, must have been quite large, and its site is clearly indicated; the coronal plates curve towards the periproct exactly as in *Pygaster* or the Nucleolitidæ; and I have no hesitation in placing the Persian forms among the Echinoidea Exocycloida.

In spite of their great resemblance to *Mesodiadema* and *Loriolella*, they cannot find a home in either of those Endocyclic genera—they are not *Pygasters* (nor, indeed, Holectypoids), and there is certainly no other Irregular genus into which they could be forced. Their affinities will be discussed later; but their difference from all known types is of such a nature that a new genus, and even a new family, are needed to give it expression.

(ii) Diagnoses and Description.

Pseudopygasteridæ Fam. nov.

Euechinoidea, Irregularia, ? Nucleolitoida, of subglobose form and subpentagonal ambital outline. Apical system almost unknown; apparently large and eccentric posteriorly. Peristome proportionately minute, practically central, with ? feeble branchial incisions, but no perignathic girdle (hence edentulous?). Periproct very large, posteriorly exocyclic, on the adapical surface, probably

related to apical system as in *Plesiechinus*. Ambulacra exceedingly narrow, homogeneous, built (? exclusively) of small, low primaries bearing small, approximately similar granules. Pore-pairs minute, homogeneous and uniserial ? throughout. Interambulacra proportionately very broad; built of low, bent plates each bearing a single scrobiculate, ? perforate, primary tubercle near the adradial margin, and sundry scrobiculate granules scattered irregularly among the abundant fine granulation. Primary tubercles never large, but notably reduced on the adapical surface, Radioles, etc., unknown.

PSEUDOPYGASTER Gen. nov.

(Genotype: *P. eos*, Middle Lias.)

Pseudopygasteridæ with the characters of the family.

PSEUDOPYGASTER EOS sp. nov. (Pl. IX, figs. 1–6.)

(Holotype: Brit. Mus., No. E, 16505, Lower part of Middle Lias, Kelat Valley, Persia. Paratype: Brit. Mus., No. E, 16506, same horizon and locality.)

Measurements in millimetres.

Ant. post. diameter		40·8 = 1
Max. Transv. diameter		42·5 = 1·04
Height	c.	22·5 = 0·55
Apical system (axis 2 — V)	?	25·0 = 0·61
Peristome	c.	3·4 = 0·08
Periproct (greatest width visible)		7·2
Interambulacrum (width on ambitus)		22·0 = 1
Ambulacrum (width on ambitus)		2·0 = 0·09
Plates in interambulacral column on adoral surface	?	7
No. of amb. plates to one iamb. (on ambitus)	c.	10

The ambital outline (Figs. 1, 2) is subpentagonal, with the angles equally truncated. The angles of the resulting decagon coincide with the main interradial tubercle-series. The posterior interambulacral margin is strongly concave. The ambitus is very tumid (Fig. 3); the adapical surface is roughly hemispherical, the adoral surface almost flat. The apical system is invisible, save possibly for the distal angle of the madreporic genital and the site of ocular V as determined by the tapering of the ambulacrum (see Fig. 1); it must have been proportionately large, and will have been centred on a point well behind the adapical pole. The peristome (Fig. 2) is almost exactly midway between the anterior and posterior margins; but, making allowance for the concavity of interradius 5, is very slightly in front of the centre. Its margin is apparently circular, with doubtful traces (in negative) of very feeble branchial incisions, but no indication whatever of perignathic

structures, whether radial or interradial. Only the posterior part of the periproct (Fig. 1, 3) is exposed; this is almost vertical in situation (owing to the inflation of the test), and extends with subparallel sides to about the ambital level, there closing rapidly (with slight asymmetry) to an obtuse angle. The exposed portion is definitely exocyclic.

The ambulacra (Fig. 5) are extremely narrow, straight, faintly convex transversely, and less prominent than the interradial carinae. The plating is entirely primary in visible parts, but may have been more complex towards the peristome, where a slight increase in width suggests development of a small hypophyllode (see Fig. 2). The small plates are perforated by very minute pore-pairs near to their adradial margins; each bears a granule perradially, and many support two, when the inner (perradiad) granule is very insignificant in size. The outer (main) granules are subequal, but those on every third plate are perhaps a little larger than those intervening. There are about ten ambulacrals to each interambulacral plate on the ambitus.

The interambulacra are very broad (Figs. 4, 6), and obtusely carinate at a distance (on the ambitus) of 3·5 mm. from the adradial sutures; they are slightly tumid along the interradial lines, except in the case of 5, which is markedly concave in that region. The plates are low and broad, especially on the adapical surface; their transverse margins are deflected adorally in crossing the carinae; those of area 5 are sharply bent adorally near the periproct (see Fig. 3). The ornament is profuse; a single series of primary, scrobiculate, ? perforate tubercules is placed on each carina; these tubercules are fairly large (diam. of scrobicule 1 mm.) on the adoral surface, but become suddenly reduced on the ambitus (and above) to a diameter of only ·5 mm., perhaps increasing again near the apex. The rest of the plate-surface is covered with a granulation approximately homogeneous, but including occasional scrobiculate granules larger than the rest. No determinable order appears in the arrangement of the minor ornament.

Note.—Both specimens are preserved in a pale grey limestone of great hardness and almost lithographic texture. In the holotype the greater part of the test is wanting; the remaining fragments are of a yellowish colour, and display the ornament in a much weathered condition. Part of amb. 1, round about the ambitus, shows the sutures very clearly. Much of the adapical surface is obscure, partly by fracture, and partly by incrustation. The region of the "posterior surface" around the periproct seems to have been scraped with a knife, but very little thickness of test has been removed. The peristome is blocked by a shell, and, since the test is missing there, there is some difficulty in determining its true outline. The paratype has been carved out of its matrix, and also broken into three pieces. It is slightly more acutely

pentagonal than the holotype, but shows nothing distinctive save the peristome, which agrees absolutely with that of the more complete specimen.

(iii) Comparisons and Discussion.

There can be no question as to the approximation of *Pseudopygaster* to *Loriolella*. Save for its absolute "Irregularity" it shows few features of difference worthy of more than specific separation. The apparent feebleness of the branchial incisions in *Pseudopygaster* might be considered an important contrast; but in view of the unsatisfactory preservation of the two specimens, it seems unsafe to lay much stress on this point. The relationship between the two genera can be expressed in the following way: if fresh material of *Pseudopygaster* should prove that I am mistaken in my belief in the absence of the fifth genital plate, or if new specimens of *Loriolella* should show that Lambert has wrongly ascribed such a plate to that form, then the question of including the new genus in *Loriolella* would be open to discussion, although the species certainly cannot be merged in *L. ludovici*. I have no anticipation of the former contingency, and should be surprised if Lambert's statement proved incorrect, although I know of no evidence in its support. It is an interesting commentary on current classification that, in the light of present knowledge, these two genera stand together so closely as to suggest unity, but between them there is a "great gulf fixed", by which they are destined to remain in two different subclasses! The anomaly is rendered more startling by the conception that *Pseudopygaster* must surely have been virtually a *Loriolella* in earlier ontogeny!

Although the general form and aspect (and, of course, the periproct) of *Pseudopygaster* are in strong contrast with those of the various species referred to *Mesodiadema*, many of the details of the one are extremely like those of the others. The diagnoses of *Mesodiadema* given by Bather (1909, "Triassic Ech. of Bakony") or Lambert (1911, loc. cit.), taken separately or combined, could be applied almost verbatim to *Pseudopygaster*, omitting the word "Diadematoid" from the former and the phrase "Test de petite taille" from the latter. Indeed, the inconspicuous character of the branchial incisions in the Orthopsid genus brings it nearer to *Pseudopygaster* than *Loriolella*, with its "scissures—assez profondes". Perhaps the large size of the apical system in the last-named types may counterbalance this feature; since the apex of *Mesodiadema*, though unknown in detail, seems not to have been very extensive. Nevertheless, on the evidence available, its exocyclic periproct is the only satisfactory peculiarity of *Pseudopygaster*, when compared with *Mesodiadema*, although size and form provide a superficial distinction. In this connexion it is interesting to notice that the tubercles in Triassic species of *Mesodiadema* had confluent scrobicules, and that the proportionate size of the tubercles is much reduced in Liassic form (see Figs. 7, 8).

The contrast between *Pseudopygaster* and the Cidaridae is great, but there are three counts on which comparison is profitable. The unituberculate nature of the interambulacral plates is one of these resemblances, but this is somewhat discounted by the exceedingly non-Cidarid proportions of the tubercles. However, it suggests a lack of progress in this feature of *Pseudopygaster*. A more striking comparison is found in the narrowness of the ambulacra and the relatively great number of ambulacral plates. Ten ambulacrals to each interambulacral (the condition at the ambitus) represents a proportion about twice that normal to "Diadematoid" or "Exocyclic" types (excluding forms with elaborate plate-combination), while the extreme narrowness of the areas enhances their resemblance to Cidarid ambulacra. Again, the large size of the apical system might indicate Cidarid affinities.

Lastly, the assumed magnitude of the apical system is certainly suggestive of "Calycine" relations, but in the absence of evidence as to the composition of the region nothing further can be said in this connexion.

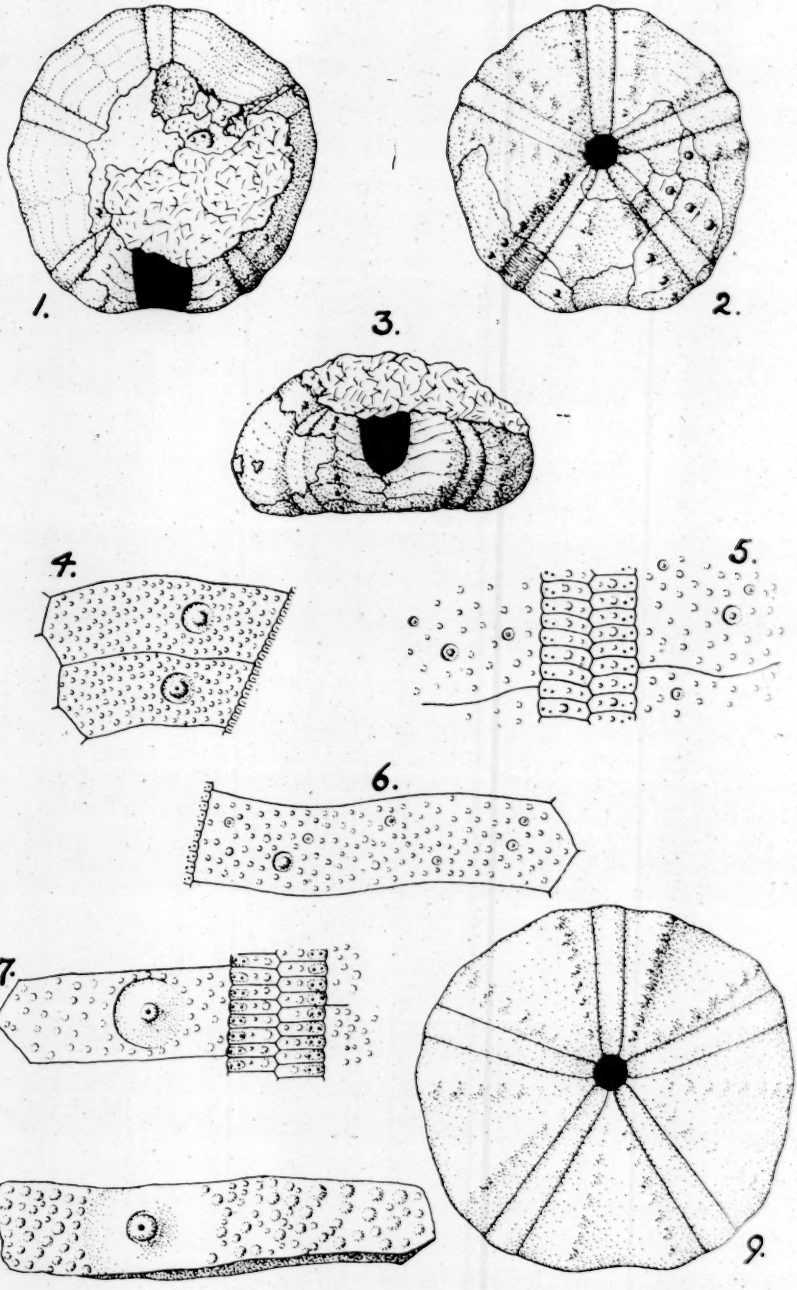
Plesiechinus, in respect of its small departure from "Regularity" and its chronological position, would seem to be the most appropriate of known Exocycloida for comparison. Further, it is regarded almost universally as the probable ancestor of all Irregular Echinoids. But size and periproct position are the only features where *comparison* with *Pseudopygaster* is possible, and even the latter of these shows many important differences. Contrast is the dominant impression when the two genera are considered together. *Plesiechinus* has a large, gnathostomatous peristome deeply embayed by branchial incisions; in *Pseudopygaster* the corresponding qualities are small, almost certainly edentulous, and practically negligible notches for branchiae. The ambulacra of *Plesiechinus* are almost one-third the width of the interambulacra, and consist of plates (mainly primaries) with well-defined perforate tubercles set in ternary arrangement; *Pseudopygaster* shows ambulacra hardly one-tenth of the ambital width of the intervening areas, built of primaries (perhaps not entirely so near the peristome) with inconspicuous granules fairly evenly distributed, and no tubercles. *Plesiechinus* has several columns of tubercles in the interambulacra in addition to a practically median "Cidaroid" column; *Pseudopygaster* has but the single column of interradial tubercles, eccentric in position. To summarize, *Plesiechinus* is a typical Holectypoid, and *Pseudopygaster* is just as definitely not a member of that order.

Excluding an imperfectly known member of the Collyritidae, *Galeropygus* remains the sole Liassic genus of Irregular Echinoids with which comparison is feasible. And it must be admitted that, at first sight, there appears little promise of such a comparison proving fruitful. However, the hemispherical outline of *Pseudopygaster* proves, on closer analysis, the only striking contrast

between the two genera; while the correspondence in detail seems too close and too comprehensive to be merely fortuitous. Remove the interambulacral tubercles from the adoral surface of *Pseudopygaster*, and the resulting aspect is almost exactly that of *Galeropygus*. Even the ambital outline, with the more prominent angles on the interambulacra, is in agreement; the straight, narrow ambulacra, with suggestion of slight orad expansion into incomplete hypophyllodes surrounding a faintly eccentric, proportionately minute peristome could hardly be more alike. The very slight degree of asymmetry in the peristomial aperture, and the lack of dental armature are additional resemblances; but, in view of the preservation of *Pseudopygaster*, must not be unduly emphasized. Further, I am of opinion that *complete* obliteration of the interradial tubercle-series of *Pseudopygaster* would weaken the comparison. On the adoral surface of *Galeropygus* two blunt carinae, reinforced by knobs situated on or near the transverse sutures, pass up the interambulacral columns to disappear at the ambitus (see Fig. 9). The transverse sutures sway adorally in crossing these carinae, which may well be considered as relics of the abandoned tubercle rows. *Pseudopygaster* shows approximate atrophy of the tubercles above the ambitus; and, while it is possible to ascribe some adaptive purpose to this phenomenon, the "law of localized stages in development" would suggest that subsequent derivations from *Pseudopygaster* would show progressive decrease in major tuberculation. Again, the sporadic occurrence of scrobiculate granules on the adapical surface of *Pseudopygaster* would produce, by an increase in their number relative to the normal granules, an ornamentation precisely like that of *Galeropygus*.

In the matter of the periproct an element of contrast appears. That aperture in *Pseudopygaster* is broad and extends to the ambitus; in *Galeropygus* it is narrow and rarely covers half the distance between the apex and posterior margin. The deep posterior sulcus of *Galeropygus* seems foreshadowed by the shallow invagination around the exposed parts in *Pseudopygaster*; and its depth in the former genus is probably connected with the depressed shape of the test. The apical system shows marked differences, assuming that its dimensions in *Pseudopygaster* are correctly determined; for that structure in *Galeropygus* is exceptionally small in area. However, a morphogenetic sequence back from *Galeropygus* would almost certainly imply a tendency towards Cidaroid qualities, and would thus involve increase in the relative dimensions of the apical system.

It thus appears that *Pseudopygaster* shows closer correspondence with *Galeropygus* than with any other Irregular Echinoid, although its affinities, Irregularity apart, are much more with the primitive Orthopsidae such as *Mesodiadema* and *Loriolella*. At least, it has only the remotest connection with the Pygasteridae. It is, of course, possible to dismiss this new type as a blind



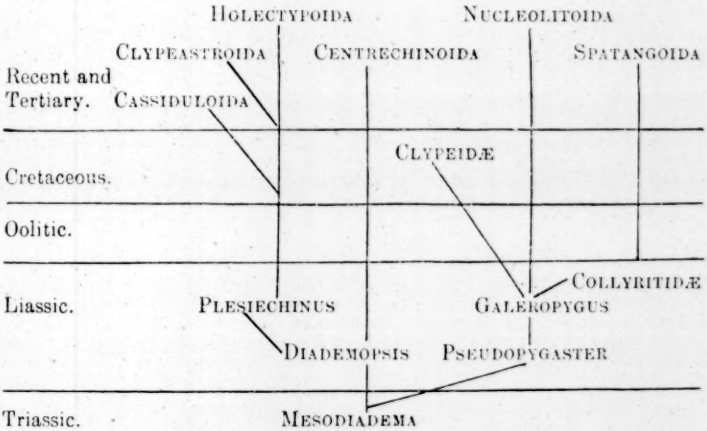
H. L. H., del.

PSEUDOPYGASTER EOS, GEN. ET SP. NOV., WITH MESODIADEMA AND GALEROPYGUS.

To face p. 221.

offshoot from the Orthopsid stock, bridging the gap between Endocyclica and Exocyclica, but leading nowhere. But in view of the evidence at present available, the possibility of a direct sequence to *Galeropygus* seems equally likely. If further material, more satisfactorily preserved, should be forthcoming, the latter alternative may well appear preferable. And, in such an event, a radical change in classification of Irregular Echinoids would result. The whole "Exocyclic" series would prove diphyletic, the Holectypoida and Nucleolitoida being divergent stocks, practically synchronous in appearance, but quite distinct in origin. Such is the interpretation that I incline to give of the new type here described; but without better material the following scheme must be regarded as purely tentative and in some measure hypothetical.

DIAGRAM OF PROBABLE LINES OF DESCENT AMONG IRREGULAR ECHINOIDS.



EXPLANATION OF PLATE IX.

FIG.

1.—*Pseudopygaster eos* (Holotype), adapical view.
2.—*P. eos*, adoral view.
3.—*P. eos*, posterior view.
4.—*P. eos*, two interradial plates below the ambitus.
5.—*P. eos*, part of Amb. I almost on ambitus.
6.—*P. eos*, an interradial plate above the ambitus.
7.—*Mesodiadema marconissae* (after de Loriol).
8.—*M. latum* (after Bather).
9.—*Galeropygus agariciformis*. Adoral surface. (The "knobs" on the interradial carinae are slightly over-emphasized.)

POSTSCRIPT.

With this note the series of papers under the title "Morphological Studies on the Echinoidea Holectypoida and their Allies" is brought to conclusion. This does not imply that I have written all I hope

to write on the subject, but that the series would obviously continue as long as I live unless arbitrarily checked. An endless serial tends to become a nuisance, especially when the complexity of the plot produces a succession of virtually distinct "short stories". Distractions from research crowd upon me (as witness the spasmodic appearances of the later parts of the series), and distractions among the Echinoidea themselves render inconvenient the restriction imposed by a specialized title. I can only hope that future workers will find some useful information (or even provocation) in the twelve notes here completed, and can confidently claim that the series concludes with a suitable climax. Those who care to read, in chronological order, the twelve papers and the larger work (*Phil. Trans.*, 1920), which is really a member of this series, will detect a gradual growth of suspicion that the Holectypoida may not, after all, be the ancestors of the whole group of Irregular Echinoids. Slowly that conception has grown as a result of comparative studies, and here I am able unexpectedly to submit a tangible, though far from satisfying, fragment of evidence in its support. Encouragement of such a nature may permit the closing of a series of papers, but cannot fail to open new, and wider, prospects of research.

A Quartz-Eyed-Gneiss from Mesopotamia.

By Dr. Hans Reusch, late Director of the Geological Survey of Norway.

THE great winged man-lions from Mesopotamia are some of the most conspicuous and most wonderful objects in the British Museum. When visiting that museum last September I was greatly interested as a geologist in examining the kind of rock of which they

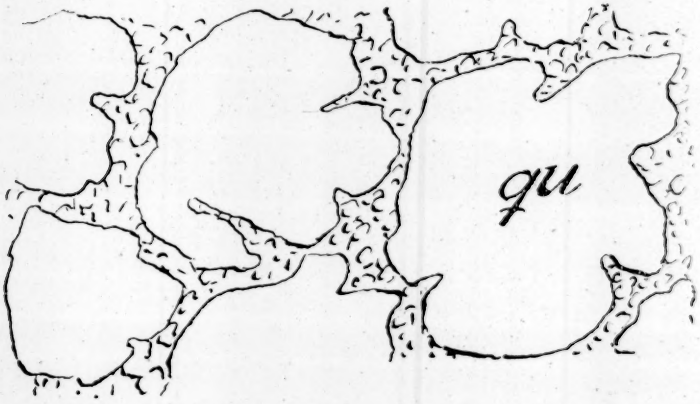


Fig. 1.—Irregular quartz fragments embedded in matrix of sparagmite, eyed-gneiss, Mesopotamia: natural size.

are composed. This rock is, I suppose, usually taken to be a granite, but it is not an igneous rock. On the contrary, it is of sedimentary origin, a felspathic sandstone (arkose or sparagmite) of very coarse grain, almost bordering on a conglomerate. In the most characteristic variety, from the palace of Sargon, the chief constituent is white quartz in lumps varying in size between that of a hazel-nut and an apple (see Fig. 1). These are embedded in a cement of coarse-grained sparagmite. A notable peculiarity is that the fragments of quartz have very irregular contours, giving the appearance of an invasion of the larger fragments by the groundmass. In other varieties (Palace of Assurbanipal) the fragments of quartz are smaller and may in some cases show no distinction from the quartz-grains of the groundmass.

This type of rock is an old acquaintance of mine, being a quartzose-eyed-gneiss such as I have described from the neighbourhood of Bergen, in Norway,[1] but the oriental variety, with larger quartz-fragments, is a more glorious rock; indeed, to a petrologist it is a wonderful sight, a rock which has been preserved without weathering in a remarkable way for many centuries.

FIG. 2.—Folded granite veins in eyed-gneiss, Mesopotamia: one half natural size.

There are only very indistinct traces of stratification or none at all, but a study of the Norwegian locality has convinced me of the sedimentary nature of the rock. The Bergen occurrence belongs to the Ordovician system, which by regional metamorphism has been converted into crystalline schists: the oriental rock is also obviously metamorphic. The variety from the palace of Sargon is seen to contain small granitic veins, closely folded as in Fig. 2.

I do not know whether the place is known whence the ancients got the material for these remarkable monuments. The rock is so characteristic that there should be no difficulty in fixing the locality.

[1] Reusch, Silurfossiler og pressede Konglomerater i Bergensskifrene, Kristiania, 1883, and (German translation) Die fossilienführenden krystallinischen Schiefer von Bergen in Norwegen, ausg. von R. Baldauf, Leipzig, 1883.

A Recent Exposure of the "Marine bed", Hordle, Hants.

By M. E. J. Chandler.

(Numbers in brackets refer to the Bibliography at the end.)

DURING part of the year 1920–1 the much-discussed "Middle Headon Marine" bed was again exposed in the cliffs near Milford, in such a position that there could be no doubt of its being truly in situ. No records on this subject have appeared for nearly forty years, and the recent exposure has given an opportunity of verifying the observations of earlier writers, and of explaining the discrepancies which occur in their several accounts.

The exposure, which was only 20 feet long, was seen some 14 yards to the west of the cliff steps opposite the Victoria Hotel, Milford; it must, therefore, coincide approximately in position with the exposures noted by Searles Wood (1) and Wright (2), and with the deposit reached by Keeping and Elwes in their trial-pit in 1883 (8).

The succession is described below, while for purposes of comparison sections of the same beds as developed to the east and west are also given in order to show the changes in facies which occur.

Western development; cliff-section a little to the east of Hordle House.		Section in the cliff below Victoria Hotel.		Easterly development; cliff-section near Paddy's Gap.	
ft. in.		ft. in.		ft. in.	
	Gravel.		Gravel.		Gravel.
3 0	Greenish marl.	4 0	White sand.		
6 6	Dark streak 2 in., with teeth, bones. Green marl, weathering white, thick with *Limnaea* and *Paludina*, about 1 ft. (= Limnaea Marl or Rodent Bed).	1 9	Marine pocket, 10 in. White sand, few marine shells, 6 in. Marine pocket, 5 in.	10 0	White sand with occasional green clayey streaks.
	Pale greenish-brown clay passing into white sands, passing into	3 0	White sands with occasional thin clayey streaks, passing into		
2 0	Laminated clays, purple-grey with *Paludina* and *Unio*	2 0	Laminated clays as in column 1.	2 0	Laminated clays as in column 1.
	Limnocarpus Band thick with seeds of *Limnocarpus*, and with *Paludina*, *Unio*, and *Melania*.		Limnocarpus Band as in column 1.		Limnocarpus Band as in column 1.

The marine bed occurs as pockets, composed almost entirely of whole shells or of shell fragments, in the white sands (Fig. 1). The highest pocket was lenticular, about 10 inches deep at the thickest point. There was a similar pocket 6 inches below it, whose western extremity was obscured by much vegetation-clad debris. In the 6 inches of sand between the pockets a few scattered marine shells were found.

The fossils agreed closely with those from the Marine bed in the Keeping Collection, Sedgwick Museum. There could be no doubt as to the identity of the deposits. The following were obtained :—

Ancilla buccinoides, Lam.
[= *pyrgota*, Edws.]
Balanus unguiformis, Sow.
Bayania fasciata, Sow.
Bulla estuarina, Edws.
Cancellaria (*Bonellites*) *muricata*, Wood.
Cardium ?
Corbula cuspidata, Sow.
Cyrena obovata, Sow.
,, *pulchra*, Sow.
Cytherea suborbicularis ?
Lepton nitidulum Wood.
Lucina albella, Lam.
Melania acuta, Sow. [= *muricata*, Wood.]
Melanopsis subfusiformis, Morris.
Murex sexdentatus, Sow.
Mya angustata, Sow.
Natica labellata, Lam.
,, *Studeri*, Bronn.
Neritina aperta, Sow.
,, *concava*, Sow.
Nucula deltoidea, Lam.
Odontaspis elegans, Ag.
Ostrea velata, Wood.
Paludina lenta.
Pisania (*Tritonides*) *labiata*, Sow.
Planorbis sp.
Potamides funatus, Sow.
,, *pseudo-cinctus*, D'Orb.
Scalaria laevis, Morris.

These fossils were identified by comparison with the Keeping collection, where they were almost all represented. The only new record of importance was the occurrence of *Odontaspis elegans*. Marine, brackish, and freshwater fossils occurred side by side, and the shells were mostly so crushed and worn that the larger ones were hard to obtain entire.

A glance at the table on p. 224 shows that eastwards the white sands attain a greater development, but to the west, on the contrary, they diminish in importance and quickly pass above into greenish marls, which include the Limnaea Marl and extend to the base of the gravel.

The controversies relating to the Marine bed are really concerned with its position in the Hordle cliff-section relative to the Lower Headon Freshwater beds.

The earlier writers, Searles Wood and Wright (1, 2), believed it to be intercalated between a Lower and an Upper Freshwater Series, a statement disputed later by Tawney and Keeping (4), as it was clear from the descriptions that the Upper Freshwater series consisted of the Unio clays and white sands which constitute the highest beds of the Lower Headon Freshwater Deposit. The clue to the situation is, however, furnished by Searles Wood himself, for in his paper he stated that he considered the portion of cliff to the east

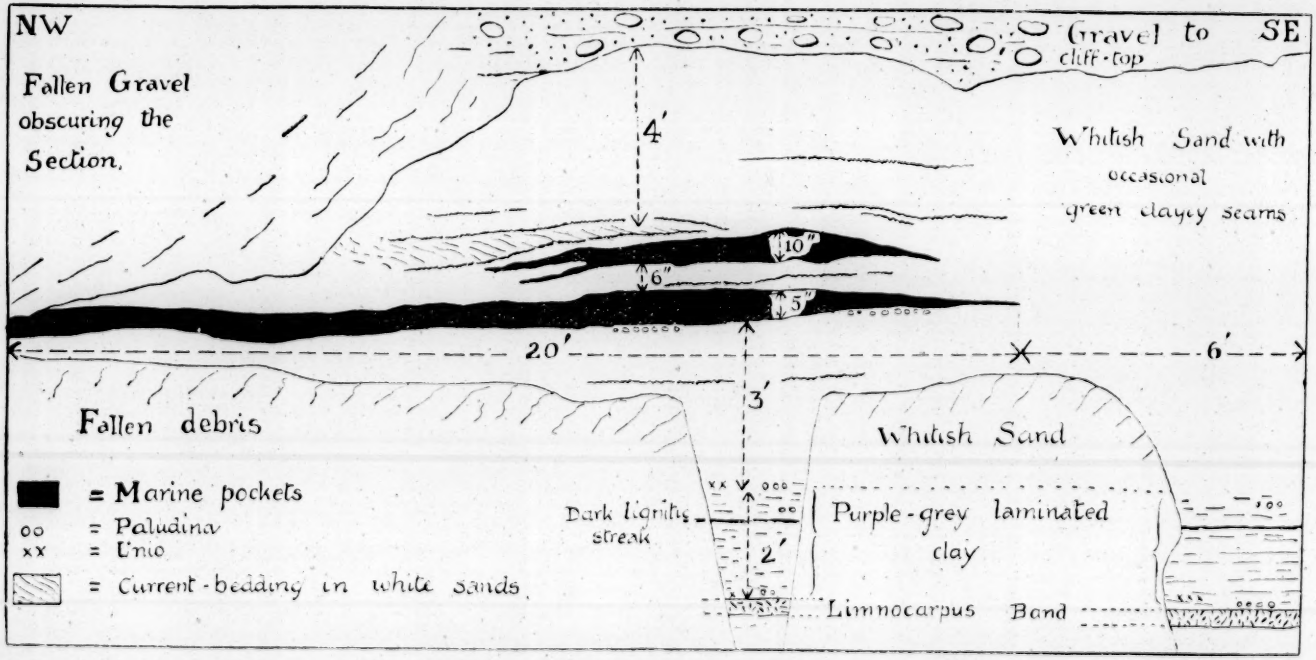


FIG. 1.—Section in the Hordle Cliffs, below the Victoria Hotel, Milford-on-Sea, to show the mode of occurrence of the "Marine Bed".

of the marine bed as the Upper Freshwater, "more from position than from its organic contents. Indeed," he adds, "I am not acquainted with any species peculiar to this stratum; for I have found all . . . in the Lower Freshwater at Hordle."

If the gentle south-easterly dip of the Headon series prevailed throughout the cliff-section, then the easterly position of the freshwater beds under discussion would necessitate their being higher in the sequence than freshwater beds to the west. But towards Milford the dip decreases, and the beds are all but horizontal; consequently successively higher strata are *not* brought into the section, and the clays and sands seen are still a part of the Lower Freshwater series, and, as such, can be traced more or less continuously far to the west.

The next published observations are those of Barbara, Marchioness of Hastings (3). She said that the highest bed of the Lower Headon was 6–8 feet of greyish sand without fossils in the upper part, but about half a mile from the point where the bed rises, a narrow dark clay band containing crushed rodent-jaws and bone fragments was seen at its base. Below the dark band there was an incompletely consolidated limestone, 5–10 inches thick, consisting of an agglomeration of *Limnaea* and *Paludina*. These beds constituted her division 1 of the series. Her dark band and associated shell marl clearly correspond to the Limnaea Limestone and overlying dark layer with teeth, given in the table on p. 224, column 1, the greyish sands to the thickness of barren sands near Paddy's Gap further east, "where the bed rises." In common with Searles Wood and Wright she evidently regarded the beds (sands) in the east as higher than those (marls) found in the west, but otherwise the facts that she states are quite in keeping with what is now seen.

Her second bed is the Marine bed which she states clearly is the lateral (easterly) equivalent of the Limnaea marl and dark clay (part of her bed 1). Her third bed is the purple-grey laminated clay, so that her observations are strictly in accordance with the facts recently noted, though she does not emphasize them and would appear to have missed their probable significance.

The attitude of Tawney and Keeping in 1883 (4) was in large measure responsible for the subsequent disagreements. They began by assuming that the Marine bed was the *Middle Marine Headon* of the Isle of Wight, and *must*, therefore, lie above the whole series of Lower Headon Freshwater beds. Hence the section for which they contended was as follows:—

	Gravel.	
	Middle Marine Headon.	
Bed 33	Green clay	3 feet.
	Brownish carbonaceous clay . . .	1 in.
Bed 32	Limnaea marl, bones, *Limnaea*, *Paludina* passing into . . . . . Pale greenish brown clay . . .	1 ft. 10 in.

Bed 31 .	Pale greenish clay with sands, sands predominating. Few fossils near the top. Alternating laminated purplish-grey clay and sands with *Unio*, *Melania*, *Paludina*	7 ft. 10 in.

I have read and re-read their paper carefully, and certain passages in it can only be regarded as a confession that the Marine bed had never been seen in the position here indicated, though for the reason given above they placed it there. For the same reason they also contradicted the Marchioness of Hastings' statements, asserting that she had inverted the order of her beds so that her number 2 (marine) should come above her number 1 (Limnæa marl in the west, white sand in the east), and they considered it impossible that 6–8 feet of grey sand could occur above the marine bed as she had observed.

Shortly afterwards Elwes drew attention to work undertaken by himself and Keeping, in the hope of settling the disputed points (8). A pit was dug to the west of Paddy's Gap, and the succession seen therein was as follows:—

Soil, 1 foot.
Gravel, 25½ feet.
Whitish sand, 1–1½ feet.
Marine bed, 1–1½ feet.
Light bluish-green clayey sand with *Paludina* and *Unio*.

This would give the Marine bed the same sort of position in the sequence as shown on p. 224, column 2, i.e. above the Unio bed, and within the sandy bed, which is the topmost horizon of the easterly development of the Freshwater series.

The great stumbling-block has evidently been the failure to appreciate the variability of these freshwater strata when traced laterally; making due allowance for this, the apparently discordant records can easily be explained. The changes that occur may be merely a question of thickness, or, according to the position in the cliff, they may concern the general character of the beds. In proof of this one has only to look at the three distinct vertical sections on p. 224, which were taken at intervals through the same beds within a space of less than half-a mile. Of these sections that in the middle column agrees essentially with Elwes' and Keeping's trial hole section, and with the easterly section with white sands implied by the Marchioness; that in the first column agrees with the Marchioness's westerly section, and with the one given by Tawney and Keeping, omitting the Marine bed which had never actually been seen in that position.

With regard to the stratigraphical significance of the Marine bed, the field evidence strongly supports the view advocated by Judd when the subject was under discussion in 1883 (7). The character of the deposits is all in favour of their being formed as pockets in brackish water, due to temporary incursions of the sea. The massed,

broken shell-fragments and the admixture of freshwater and brackish water shells suggests that in exceptional storms large tidal waves rushed further westward up the estuary than usual, or broke across some barrier, by which they were ordinarily excluded. Each such incursion might be marked by the formation of a "marine" pocket in the midst of the white sands, which were being deposited at this time under more tranquil, normal conditions. Further west, beyond the immediate influence of such incursions, calcareous marls with a thriving freshwater molluscan fauna were being deposited approximately contemporaneously.

The whole matter was, indeed, rightly estimated by Judd when he stated that "the importance of this so-called 'marine-band' . . . has been much overrated. It is not a distinct formation . . . but only one of numerous local intercalations of brackish-water bands, among the Oligocene strata of this area."

My thanks are due to Professor Marr, F.R.S., for allowing me access to the Marine bed material in the Sedgwick Museum.

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REVIEWS.

THE GEOLOGY AND MINERAL RESOURCES OF THE SERB-CROAT-SLOVENE STATE. By D. A. WRAY. pp. 107, with 4 plates and 10 figures. Published by the Department of Overseas Trade. H.M. Stationery Office, 1921. Price 3*s.* 6*d.*

THIS publication was originally a confidential report by the Geologist attached to the British Economic Mission to Serbia in 1919; it has now been made available for general circulation. It is obvious that Mr. Wray undertook no light task, which he has carried out in an admirable manner, and the Report should be of the greatest use to those interested in the mineral resources of this new state. Part ii contains a summary of the physiography and geology of this highly complicated and very variable area, where a large number of formations are represented and the structures are most complex, the dominant tectonic feature being the Dinaric series of folded chains. Jugoslavia now includes most of the well-known Karst country, where limestone scenery reaches perhaps its highest development and its most unfavourable economic possibilities, but the state has also got possession of much fertile country in Croatia, Slavonia, and the Banat. In reading this report some of the new forms of place-names are rather puzzling and it was some time before the reviewer was able to recognize Laibach in its modern disguise of Ljubljana.

A very full account is given of the coal resources, which are almost entirely Mesozoic brown coals or Tertiary lignites. Of these the total reserves available are very large and coal-mining should have an important future. There are also promising deposits of iron ore, especially in Bosnia, as well as most other metals in some quantity; on the whole, Jugoslavia must be described as a well-mineralized region, though development is much hindered at present by poor transport facilities in the mountainous regions, where most of the ore-deposits naturally lie. Bauxite and magnesite also exist and there are possibilities of oil in Croatia, where some has already in fact been proved. It is important to note that the famous mercury mines of Idria have been taken over by Italy since this report was written. Under improved economic conditions the mining industry of Jugoslavia should be a source of prosperity to the state.

THE KARROO DOLERITES OF SOUTH AFRICA: A STUDY IN HYPABYSSAL INJECTION. By A. L. DU TOIT. Trans. Geol. Soc. S. Africa, vol. xxiii, 1920, pp. 1–42.

IN this important paper Dr. du Toit discusses with much originality and insight some of the phenomena presented by the intrusion of the Karroo dolerites. It is to be feared, as remarked by the author, that few European petrologists recognize the extraordinary character of this tremendous phase of igneous activity, undoubtedly one of the most wonderful

events in the world's history, whether we consider the vast mass of material concerned or the complexity of its relations. Even now the area of injection covers at least 220,000 square miles, and a considerable part of its original extent is doubtless beneath the Indian Ocean; vast numbers of the sills and sheets are from 100 to 300 feet thick, while individual laccolithic swellings, such as those of Ingeli and Insizwa, run up to 3,000 feet, and the Andriesbergen sheet in the Queenstown district is 1,500 feet thick over an area of 40 square miles. The intrusions show every possible variety of form between flat sills and vertical dykes, as well as laccoliths, bosses, and plugs, and often a sheet gradually turns down and passes into a dyke-like body. In the Eastern Province of Cape Colony and in Natal it is estimated that dolerites constitute about 20 per cent of the whole Karroo system, and in places the ratio rises to 30 per cent. It is therefore obvious that such a phenomenon is worthy of thorough investigation.

A very striking feature is the uniformity of the rocks: apart from the thick laccoliths, where there has been marked differentiation into ultrabasic and intermediate types, they are all essentially dolerites, either with or without olivine. In this paper only sufficient petrographic details are given to elucidate the special points under discussion. The author mainly deals with the tectonics of intrusion.

It is shown that there was a close connexion with the eruption of the Stormberg volcanics and probably with those of the Lebombo, and all the phenomena are correlated with the diastrophic relations of the great geo-synclinal depression that bounded Africa to the south at the beginning of Jurassic time, and led immediately to the folding and thrusting of the coast ranges bounding the Karroo area to the south and west, and presumably once also to the east; the Karroo is regarded as the "foredeep" of these chains. Within this area the dolerites were intruded, the relative order of injection of the sheets being from above downwards. It is suggested that this process may be concisely described as "*descensional lit-par-lit stoping*".

The paper concludes with a comprehensive discussion of the relation of the South African geological events of this period with those of the other continents of the southern hemisphere. This is too long to summarize here, but should be read by all petrologists, since it gives a connected and correlated view of a series of events of fundamental importance in terrestrial evolution.

R. H. R.

As rochas da Ilha de S. Tomé. By A. Ferraz de Carvalho. Publicações do Museu Mineralógico e Geológico da Universidade de Coimbra, No. 1. pp. 9–24, with 5 plates. 1921.

THE Portuguese island of S. Tomé, still only imperfectly explored from the geological point of view, lies in the Gulf of Guinea, almost exactly on the equator and about 100 miles

from the coast of the French colony of Gabun. The specimens here described are all volcanic, belonging to eruptions of different ages, but showing distinct features of consanguinity. In general terms it may be said that all belong to the alkalic and peralkalic volcanic groups. They include types described as phonolites, containing nepheline and hauyne, and in one case plagioclase; phonolitic andesites with hornblende or pyroxene, hornblende-trachyandesites and camptonites; trachydolerites and alkali-basalts passing into limburgites; nepheline-basalts, tephrites, limburgites, and augitites. Descriptions of all these varieties are given in detail, illustrated by good microphotographs. The most common type is basalt, especially in the north-east of the island.

The most interesting feature of the island is a "spine" of the Pelean type, called the Cão Grande, of which an excellent photograph is given. Not far from it is found a smaller example, the Cão Pequeno, and on the slopes of the Ió Grande, there are said to be other examples.

The petrographical character of the island approximates to that of the other volcanic islands of the Atlantic, from the Canaries to Ascension, and shows close relations with the neighbouring volcanic regions of the African continent.

R. H. R.

MEMOIRS OF THE GEOLOGICAL SURVEY OF ENGLAND AND WALES. By HENRY DEWEY and C. E. N. BROMEHEAD, B.A. Sheet 270, South London. pp. vi + 92, 3 plates, and 1 text-figure. 1921. 3*s*. Map. Sheet 270, South London. Drift. Colour printed. 2*s*.

THE map covers substantially the same ground as the south-eastern sheet of the special London district map published in 1903. The area was, however, resurveyed just before the war on the 6 in. scale, and the new map is based on this survey. New features in the map are the separation of the Claygate Beds from the London Clay and an alteration in the subdivisions of the superficial deposits. Considering the denseness of buildings in the area and the somewhat complex symbols used to denote the older superficial deposits, the map is extraordinarily well printed and clear, and a welcome change from the illegibility of the new map of Anglesey.

With regard to the memoir, a considerably more detailed account of the area is given than that in H. B. Woodward's *Geology of the London District* (1909), of which a revised edition is soon to be published. The first alteration of importance is the introduction of the term Claygate Beds, proposed by Dewey in 1912. These beds are the uppermost 50 feet of the London Clay, and are practically unfossiliferous. They differ lithologically both from the London Clay and from the Bagshot Beds. They are conspicuously even-bedded, with beds of clay and sand, the latter increasing in thickness upwards. The sand is of much finer grain than is usual in the

Bagshot series. A plate is given of the type-section in Sim's Clay-pit at Claygate.

Considerable space is devoted to a description of the river terraces and flood plain gravels, and a tentative correlation is given between these deposits and the implement classification.

A special chapter at the end deals with economic deposits, the nature of the soils being described under each stratigraphical division. An excellent bibliography is provided.

The plates are very interesting, being reproductions of old prints of London with notes on the geological points they illustrate.

Taken all round, the memoir is a great boon to geologists living in the area, both as a reference book and as a most lucid guide.

J. E. A. W.

THE OIL ENCYCLOPÆDIA. By MARCEL MITZAKIS. pp. 551. London: Chapman & Hall, Ltd. 1922. Price 21*s*.

THIS book is not only what its title indicates, a dictionary of all practical matters concerned with the oil industry, but it is also something more, for it includes under the appropriate headings short summaries of the information available on many points of scientific interest, such as theories of oil-formation, the geology of oil-bearing regions, the chemistry of oil and its products, and many cognate matters. While in the compass of the short articles in this volume it is impossible to go deeply into such subjects, nevertheless, these summaries should prove extremely useful, while as a book of reference for locating little-known and out-of-the-way oil occurrences it will have great value. Short biographical notes are also given of the principal workers in this branch of industry, both scientific and economic. Where desirable references are also given to original publications.

CORRESPONDENCE.

THE MAGNESIAN GROUP OF IGNEOUS ROCKS.

SIR,—I would be glad if you would kindly afford me the opportunity of replying to the points raised by Mr. Tilley in the letter which appears in your issue of this Magazine of December last.

While Mr. Tilley acknowledges the existence of the group of rocks I endeavoured to describe, he objects to the use of the term "magnesian" on the assumption that the rocks under discussion contain notable amounts of magnesium only in the ultrabasic members; moreover, he states that it is iron and not magnesium that calls for attention in the less basic types. I have myself already mentioned the importance of the iron in my paper. As regards the magnesium, it is sufficiently clear, from the works of Holland, Lacroix, and other writers I referred to, that the high content of this mineral is far from being confined only to the ultrabasic members.

Further, I have referred to other cases in which the name of a characteristic constituent has been applied to a whole group of rocks; in these cases the name has been allowed to stand even when the special constituent is inappreciably developed in the extreme acid or basic members, or in unusual types. For instance, the alkaline and calc-alkaline suites are well-known to coincide at their acid and basic ends, and, moreover, intermediate members of the one suite can sometimes be distinguished from those of the other only by their close association with a characteristic type.

As regards the suggested list of magnesian provinces, I have admitted the possibility that further work may demand some modification, and it is certainly not to be expected that the areas named would be analogous in every respect. Nevertheless, at the time I drew up the list there appeared ample justification for the inclusion of all the areas named, but I thought it unnecessary, in a short general paper, to do more than refer to original papers. In my present circumstances, having no opportunity of consulting the necessary works again, I am unable, even if it were desirable, to put forward a detailed comparison of the various areas.

It is well known that the presence of hypersthene does not necessarily indicate a high proportion of magnesium in a rock; this also has been mentioned in my paper.

In conclusion, I may perhaps be permitted to suggest that it is still rather early to base arguments concerning the crystallization of deep-seated magmas upon chemical equations. Moreover, as regards the contact metamorphism of norites, the chemical reactions suggested by Mr. Tilley do not appear, in the case of various occurrences that have been examined in detail, to be in accord with the results of petrological examination. I believe I am correct in stating that recent additional work upon the Huntly intrusions,[1] referred to by Mr. Tilley, has indicated that the cordierite of these rocks is due entirely to absorption of sedimentary material, and not, even in part, to invasion of one intrusion of norite by another. Again, in the case of the norite complex of the Sierra Leone Peninsula, where several phases of metamorphism have been developed as a result of the invasion of earlier members of the complex by later, the actual changes observed are also very different from those suggested, especially in that no trace of cordierite has been found.

F. Dixey.

Nyasaland.
January, 1922.

[The foregoing letter was unavoidably crowded out of the April number; however, a proof was submitted to Mr. Tilley, whose reply is printed below.—Editor.]

[1] Cf. H. H. Read on "Some Contaminated Rock Magmas", paper read before Section C (Geology) at the Edinburgh meeting of the British Association for the Advancement of Science, September, 1921.

SIR,—Mr. Dixey's special pleading for the use of the term "magnesian", and for the setting up of a third great group of igneous rocks co-ordinate with the alkaline and calc-alkaline suites, carries little conviction in its train.

The impropriety of the term " magnesian " is sufficiently evident on inspection of a series of first-class analyses of rocks of the charnockite series, from any of the well-defined provinces such as those of Southern India or Western Norway.

The ground of Mr. Dixey's paper was largely covered by H. S. Washington in 1916 in his paper on " The Charnockite Series of Igneous Rocks " (*Amer. Journ. Sci.*, vol. xli, pp. 323-38), but with somewhat different conclusions. In summing up the chemical characters of charnockite provinces, he was led to state that " they are characterized by the dominance of iron oxides over magnesia and lime, the two latter being present in about equal amount ".

One word with regard to the concluding paragraph of Mr. Dixey's letter. Mr. Dixey has missed the point of my remarks if he has not perceived that the reaction discussed was in no way dependent on any intrusion of norite by a later member of the series.

The cordierite-norites of Minnesota described by Winchell (*Amer. Geol.*, vol. xxvi, 1900, p. 151) afford an even more instructive illustration of the development of hypersthene than those of the Huntly area cited. The normal gabbro from which the cordierite-norites are developed by assimilation of aluminous sedimentary material, is free from rhombic pyroxene, while the cordierite-norites are free from the monoclinic type.

The inaccuracy of the reaction I have stated for the disappearance of diopside, when cordierite appears, can be admitted when Mr. Dixey can produce cordierite-norites, which, apart from armoured relics, contain monoclinic pyroxene, as in the gabbros or norites with which they are associated.

C. E. TILLEY.

THE ENGLISH ESKERS.

SIR,—Professor Gregory scores. The passage quoted by me from the Geological Survey Memoir on the Yorkshire Coalfield does refer, I agree, to mounds which only in part belong to the Lanshaw Delves series, and not at all to the Delves themselves. *Touché!* The fact remains, however, that Carvill Lewis specifically mentions " Laneshaw Delves, and limekilns have been built upon them ". So Professor Gregory is honourably acquitted of ignoring two statements of the fact; he ignored only one. I will not labour the point of whether Russell's " four-tenths " of the great Memoir on the Yorkshire Coalfield includes the passage under discussion, but content myself with remarking that the quaint " harbour-bar " hypothesis for the Bingley Mounds is found also in his early paper in the B.A. report for 1873.

One more confession I must make. The lithographer who twenty-eight years ago transferred the Drift details from the map of the Geological Survey to illustrate my paper on the York Moraines did, to gain some private end, omit a pink spot one millimetre in breadth and I failed to detect the omission and so incur the awful penalty. Why Professor Gregory attaches any importance to it I fail to see. The rest of his criticisms of my remarks on the phenomena about York so ingeniously evade the real issue that rather than weary the readers of the GEOLOGICAL MAGAZINE with their discussion I will ask those who are interested to compare Professor Gregory's original statement with my comments and his rejoinder.

I may remark that though I adhere to my early opinion that the Fulford-Escrick ridge is an esker (using the word in a generic sense), its precise mode of formation demands careful investigation, especially in view of the occurrence of Mammalian remains in or beneath the gravel.

I must now revert to the Lanshaw Delves and their interpretation, for here are exemplified those characteristics of Professor Gregory's glacial work that, in my judgment, outweigh all the good that might conceivably be found in parts of it.

It will conduce to an understanding of the case if we suppose that Professor Gregory ascended the steep moorland path from Ilkley Station (300·6 O.D.), keeping in mind Carvill Lewis's description of the Lanshaw Delves and the signs of old lime-kilns, and the description in the Geol. Surv. Memoir of the ridges "composed of limestone-boulders mixed with pebbles and sand," . . . "They lie partly on Boulder Clay and partly on ground free from this deposit."

He finds it to consist of "sandy loam with many angular blocks of Millstone Grit similar to those strewn over the adjacent moors. . . The smaller pebbles include vein quartz and jagged fragments of black chert; and all these may have been derived from the Millstone Grit". His inference follows that this was the remains of a moraine of "an embryo corrie glacier". "The depression between the summit and the Delves faced N.E. and was probably filled with a sheet of snow and ice." The reason for coming to this conclusion in preference to Carvill Lewis's view that it was the lateral moraine of a great glacier filling the valley of the Wharfe to this altitude (about 1,180 feet) is given by implication in a passage that I must quote at length.

"The high-level eskers south of Ilkley are said in the Survey Memoir to rest partly on boulder clay, but I saw nothing to confirm this statement regarding Lanshaw Delves or any erratics, boulder clay, or other trace on the moor of any general glaciation of the district. The surface is littered with blocks of grit formed by weathering in situ. Even at the level of 600 feet in a quarry at Eldwick, on the southern side of the moor, the deep decomposition of the sandstones

indicates that there had been no glaciation at that locality. My observations agree with the generally accepted view that the hills of this district have not been covered by a general ice-sheet, and that the only extraneous ice in this part of the Aire Valley lay on its floor."

This is surely explicit—no boulder clay, no erratics (limestone here would be erratic), none but rock weathered in situ.

The allusion to the quarry at Eldwick is one of the author's most unfortunate touches. Messrs. Jowett and Maufe, two geologists who have achieved distinction by glacial work in other areas, show in their paper previously quoted by me that between this spot and the narrow crest of the moor there are six noteworthy lake-channels, two striated surfaces, one being at 1,080 feet O.D. While their map shows the ice-margin at a little above 1,200 feet O.D. This quarry, therefore, was covered by more than 600 feet of ice!

True, Professor Gregory was familiar only with the title of the paper until my criticism brought it to his notice, but as it "was entitled 'The Glaciation of the Bradford and Keighley District', I did not expect to find any account of the Delves in it". Seeing that Professor Gregory dealt also with the Drift mounds at Bingley which is midway between the two towns named, it is surprising, that he did not refer to it for that purpose; indeed, there is something humorous in the thought of Professor Gregory's profound research into the meaning of the word "Delves" with the aid of Wright's *English Dialect Dictionary* and the *New English Dictionary*, while neglecting this important paper.

As to this word Delf, every map of the district on the 6 in. or 1 in. scale would furnish examples of its common colloquial use, not in those rare and recondite senses disinterred by Professor Gregory. We have the following: "Coopers Cross Delf (Disused)," "Dry Beck Delph (Disused)," "Derry Hill Delph," "Odda Delph (disused)," in each case with hachuring to indicate a quarry, the common meaning of the word.

Now as to the occurrence of limestone erratics, Professor Gregory never mentioned them in his paper, and the whole context ascribes the Delves and their contents to the Millstone Grit, including the black chert; moreover, he says specifically that he saw no "erratics", and the whole case for his corrie glacier depends upon the Delves being beyond and above the general glaciation. Now he informs us that he did not say or conclude that there was no limestone in the Delves. Neither did he say there was no Shap granite there. In fact, he told us what he did find, and not what he did not. He now suggests that any digging in the Delves may have been to obtain limestone from underlying boulder clay—a material he was unable to find and clearly considered to be absent. This is not the scientific method, but the methods of the special pleader in the leading case of the borrowed bucket.

As it is many years since I went over the Delves, I walked the length of them yesterday. I found the lime-kilns much less com-

plete than formerly, but along the southern side alone there were at least ten quite recognizable by the craters and by the fire-reddened stones with which they had been lined, though only rarely was a part of the lining standing. As to stones, Millstone Grit was the chief constituent, black chert, often crinoidal, was quite common, but Carboniferous limestone was very rare except about the tops of the kilns, where pebbles were freely scattered. Bits of good coal could also be found near the pits. The general appearance of the Delves is very striking and—*pace* Professor Gregory—unmistakable; for the whole length of the ridge the form is quite obviously artificial—dimples, craters, and trenches everywhere modify the surface, one great trench runs for scores of yards parallel with the northern margin. On the south side spurs project, often with the crater of a lime-kiln. I confirmed my earlier impression that not a yard of the original form was preserved.

There is a small isolated knoll, "Little Skirtfull of Stones," consisting wholly of cobble-stones without infilling; this I regard as a cairn—probably prehistoric—and not a moraine mound.

P. F. Kendall.

CARBONIFEROUS NOMENCLATURE.

Sir,—All geologists, and particularly those connected with Carboniferous geology, are grateful to Dr. R. Kidston for replacing the old and provincial subdivisions of the Coal Measures by terms of correlative value, dependent on their floras as worked out by himself, Arber, and other palæobotanists. The words Lanarkian and Staffordian are both precise and euphonious, Radstockian at least precise and indicative. The fourth term, Westphalian, however, is not only "unconformable" to the others in having no "local habitation" in this country, but differs in spirit from the rest in that it seems to suggest that these, our richest measures, are not typically represented in Britain. Worse than this, the term has been preoccupied since 1893, when Munier-Chalmas and de Lapparent used the word in a wider sense, equivalent to the whole of Kidston's three lowest divisions. If, as seems advisable, the use of the term Westphalian in the restricted sense is abandoned, it would be difficult to select one more representative than "Yorkian", particularly as its only likely rival "Lancastrian" may conceivably be wanted in the end for another Carboniferous subdivision.

W. W. Watts.

Imperial College, S.W. 7.
8th March, 1922.

THE STRATIGRAPHICAL VALUE OF FORAMINIFERA.

Sir,—In view of the interest now displayed in the possibility of utilising the foraminifera associated with oil deposits as zonal fossils,

a recent paper by Dr. Rufus M. Bagg [1] is rather a shock. Dr. Bagg has examined thin slices of chert from the Bonaventure conglomerate and gives a list of forty-four species and one variety of foraminifera which he has determined; and he concludes that the cherts are of either Cambrian or early Ordovician age and probably the latter. Yet, of the forty-five kinds, no less than thirty-seven are recorded by Brady [2] as still living! One other is reported as recent by d'Orbigny.[3] Of the thirty-eight one only, according to Brady, may go back to the Silurian and that is doubtfully the same, for it is the simplest type of hyaline foraminifer known (*Lagena globosa*), a simple spheroid. Of the thirty-eight living forms two go back to the Permian and Carboniferous, and these are also simple and doubtful species (*Nodosaria communis* and *N. radicula*); eighteen are known first in the Trias; three others are known first in the Jurassic; and four others first from the Cretaceous. The whole thirty-eight living forms are also recorded from Tertiary strata.

Why, then, is this collection of foraminifera described as early Palæozoic? There are no fossils other than foraminifera recognisable specifically. The author apparently relies mainly on some foraminifera found in Cambrian rocks of New Brunswick, and described by G. F. Matthew.[4] Of these Dr. Bagg finds at Gaspé, *Globigerina cambrica* Matthew, *G. didyma* Matthew, and *Orbulina ovalis* Matthew. The author's figure of *G. cambrica* does not agree with Matthew's, while that of *G. didyma* might belong to many kinds of foraminifera. Dr. Bagg himself throws doubt on the separate existence of such subspecies as *Globigerina cretacea* or *Orbulina ovalia* (p. 38, reprint), and none of the determinations is free from doubt. His figure of *Orbulina ovalis* would do for a simple *Lagena*. Of the other four forms not now living, two are Tertiary and one of these has also been recorded by Brady as Permian and Carboniferous; the other two are Cretaceous species, but one has been described by Ehrenberg as early Palæozoic also.

It is interesting to note that, although Dr. Bagg gives a list of forty-four species and one variety, without any name being queried (three have wrong authors assigned), yet in no less than thirty-five cases, more or less doubt is expressed in the paper as to the correct determination. Thus, *Bolivina reticulata* Hantken, listed on p. 47 (reprint) as definitely identified, is described on p. 22 as follows:—

"*Bolivina* sp. . . . perhaps *B. reticulata* Hantken
Plate 3, figures 5–7.

On slide 6 (see figure 5), near the northeast corner, is a cross section of Bolivina which has five widely inflated segments in each

[1] "The Foraminifera of the Bonaventure Cherts of Gaspé": *N.Y. State Museum Bull.*, No. 219, 220. Fifteenth Report of the Director, 1918, 1921.

[2] *Reports of the Scientific Results of the Voyage of H.M.S. Challenger*, vol. ix (Zoology), 4to, London, 1884.

[3] *Foraminifères fossiles du Bassin tertiaire de Vienne*, 4to., Paris, 1846.

[4] "The Protolenus Fauna": *Trans. N.Y. Acad. Sciences*, vol. xiv, 1895, pp. 101–53.